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FINITE ELEMENT ANALYSIS OF PIPE ELBOWS

by

Melvyn S. Marcus and Gordon C. Everstine

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COMPUTATION, MATHEMATICS, AND LOGISTICS DEPARTMENT
DEPARTMENTAL REPORT

February 1980

DTNSRDC/CMLD-79/15

FINITE ELEMENT ANALYSIS OF PIPE ELBOWS

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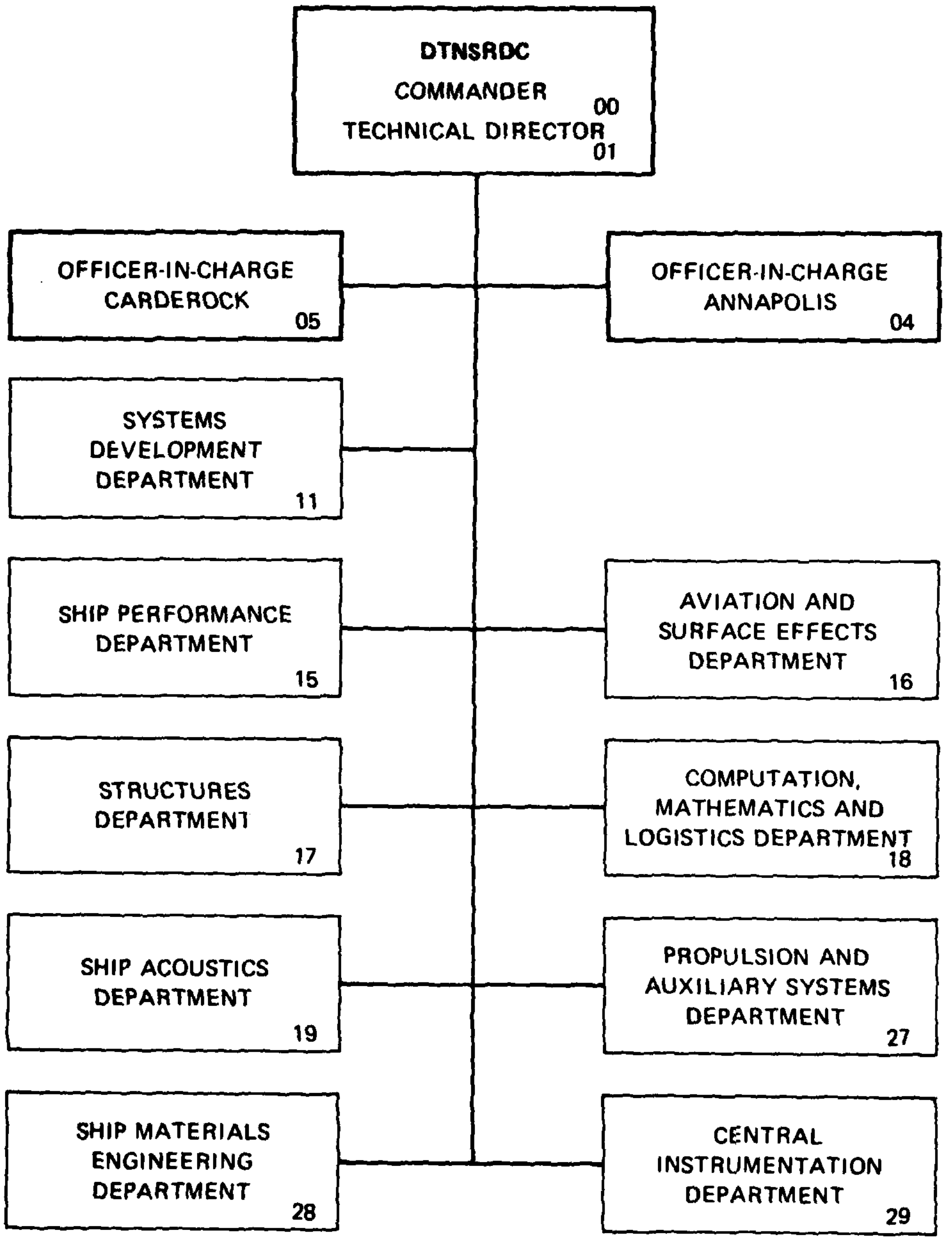

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NASTRAN analyses were performed with three different finite element models on a 90-degree pipe elbow to determine principal stresses due to internal pressure, inplane bending, out-of-plane bending, and torsion moment loadings. Comparison with stresses experimentally obtained under the four loading conditions demonstrates the adequacy of a finite element model with ideal geometry assumptions and an economical mesh spacing. Implementation of the NASTRAN modeling is described in detail. Deck set-ups for a sequence of

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computer runs to automatically generate NASTRAN input data, execute NASTRAN, and postprocess NASTRAN output are included. A sample NASTRAN data input file is also listed.

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ABSTRACT

NASTRAN analyses were performed with three different finite element models on a 90-degree pipe elbow to determine principal stresses due to internal pressure, inplane bending, out-of-plane bending, and torsion moment loadings. Comparison with stresses experimentally obtained under the four loading conditions demonstrates the adequacy of a finite element model with ideal geometry assumptions and an economical mesh spacing. Implementation of the NASTRAN modeling is described in detail. Deck set-ups for a sequence of computer runs to automatically generate NASTRAN input data, execute NASTRAN, and postprocess NASTRAN output are included. A sample NASTRAN data input file is also listed.

BACKGROUND

The objective of one of DTNSRDC's programs is to reduce the size and weight of sea-water piping systems sufficiently to achieve the design goals. This objective can be accomplished in several ways: (1) by using higher strength materials, (2) by improving fabrication techniques, (3) by better designs, and (4) by less conservative structural acceptance criteria and stress factors. The third and fourth alternatives require the application of more refined structural analysis methods such as the finite element method (FEM). With the FEM, the analyst can gain a more accurate understanding of general end point motions, which influence piping system designs, as well as of motions and stresses in the piping systems themselves.

The design of piping systems depends on a knowledge of the stresses and deflections of the pipes due to the anticipated service loads. In general, these loads may be either static or dynamic. The static category includes pressure, moment, and thermal loads; the dynamic includes shock loadings. For any of these loads, the most critical locations are usually in components such as elbows and tees. It is well known, for example, that a curved pipe does not respond to bending loads in the way predicted by elementary beam theory, which is usually adequate for straight pipes.

This report describes finite element analyses of piping elbows subjected to both pressure and moment loads. The NASTRAN finite element structural analysis computer program was used. Stresses and flexibility factors were computed, and the stresses were compared to experiment. The two main purposes of the work were:

(1) to determine modeling conditions (including mesh size and ideal geometry assumptions) for which a NASTRAN finite element analysis of the pipe elbow would yield results in good agreement with experiment, and

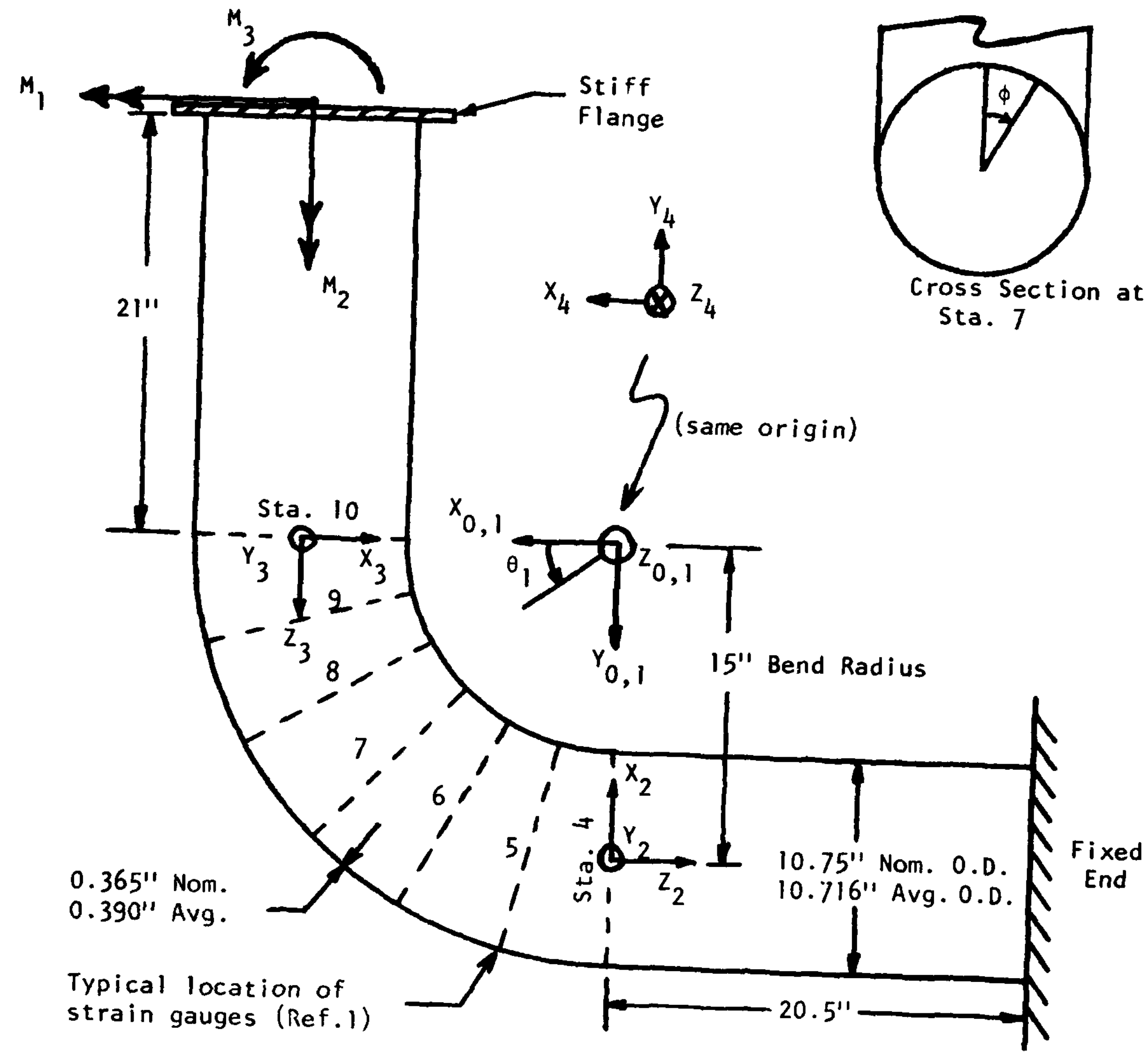
(2) to provide deck set-ups for NASTRAN data generation and solution implementation which could be used to automate a computerized parameter study of pipe elbows.

Such a study, for example, could yield basic information on the structural behavior of elbows. Also, given the increased accuracy and reliability attainable with finite element models, compared to the less precise traditional methods, the studies could be conducted in accordance with less conservative design rules similar to those of the ASME Section III nuclear pressure vessel code.

STATEMENT OF THE PROBLEM

The structure to be analyzed is the 10-inch, schedule 40, 90-degree carbon steel pipe elbow referred to as ME-1 by the Reactor Division of the Oak Ridge National Laboratory.[1*] This elbow, one of four machined at Oak Ridge to test the effects of thinning and ovalling, was machined so as to simulate as far as possible an elbow with ideal (uniform) geometry. Details on the geometry of ME-1 are shown in Figure 1. Oak Ridge also

*A complete listing of references is given on page 25.



Coord. System ID	Type
0	Rect.
1	Cyl.
2	Cyl.
3	Cyl.
4	Rect.

Figure 1 - Geometry and Coordinate Systems of Pipe Elbow ME-1

made measurements of the actual wall thickness and elbow diameter for the test model; these measurements are listed in Tables 1 and 2, respectively. All values in each table were averaged to obtain the average wall thickness and outside diameter values of 0.390 inch and 10.716 inches, respectively. Thus the average value of mean radius (to middle of wall) is 5.163 inches.

This elbow structure was subjected to four different loadings:

(1) internal pressure of 75.53 psi

(2) in-plane moment of 32,660 in-lb (M_3 = -32660 in Figure 1)

(3) out-of-plane moment of 32,660 in-lb (M_1 = 32660 in Figure 1)

(4) torsional moment of 32,660 in-lb (M_2 = 32660 in Figure 1)

These loads were also used for the analysis.

The material properties of carbon steel are $E = 2.9 \times 10^7$ psi (Young's modulus) and $\nu = 0.3$ (Poisson's ratio).

THE NASTRAN MODELS

Three analyses were performed:

Mesh A -- a uniformly spaced mesh of finite elements (Figure 2) for an ideal (uniform geometry) elbow having the same thickness and diameter throughout; the values used for the wall thickness and middle radius were the mean values computed from Tables 1 and 2: 0.390 inch and 5.163 inches, respectively.

Mesh B -- similar to Mesh A except that the number of elements in each direction was increased by 50%.

Mesh C -- a uniformly spaced mesh of finite elements for the actual elbow ME-1 as measured and tabulated in Tables 1 and 2; the mesh spacing was the same as for Mesh A, the coarser of the two idealized models.

For the ideal models (Meshes A and B), the structure is symmetric with respect to the plane $Z_0 = 0$ in Figure 1, so that only one-half of the structure need be modeled. Although the actual geometry used for Mesh C does not exhibit the same symmetry, such symmetry was assumed here also, and only half the structure was modeled. This assumption is equivalent to assuming that the nonsymmetry in the thickness variation on the unmodeled side ($Z_0 < 0$) has little effect on the solution on the modeled side

TABLE 1 - MEASURED VALUES OF WALL THICKNESS FOR ME-1

ϕ (degrees)	Wall Thickness (in inches) at						
	St. 4	St. 5	St. 6	St. 7	St. 8	St. 9	St. 10
0	0.395	0.389	0.404	0.402	0.384	0.388	0.381
22.5	0.394	0.392	0.401	0.399	0.384	0.393	0.391
45.0	0.394	0.389	0.406	0.401	0.381	0.378	0.398
67.5	0.398	0.398	0.396	0.398	0.385	0.376	0.401
90.0	0.396	0.397	0.398	0.404	0.386	0.392	0.392
112.5	0.394	0.383	0.386	0.393	0.381	0.379	0.385
135.0	0.395	0.375	0.382	0.393	0.384	0.378	0.381
157.5	0.394	0.380	0.382	0.393	0.379	0.384	0.380
180.0	0.390	0.389	0.388	0.383	0.386	0.386	0.380
202.5	0.396	0.391	0.388	0.389	0.389	0.391	0.387
225.0	0.395	0.380	0.382	0.386	0.402	0.392	0.397
247.5	0.394	0.366	0.372	0.374	0.389	0.383	0.387
270.0	0.396	0.381	0.406	0.401	0.391	0.406	0.401
292.5	0.390	0.383	0.393	0.390	0.390	0.394	0.394
315.0	0.390	0.384	0.394	0.383	0.391	0.389	0.394
337.5	0.391	0.382	0.399	0.408	0.395	0.388	0.390

Average thickness = 0.390 in.

TABLE 2 - MEASURED VALUES OF OUTSIDE DIAMETER FOR ME-1

ϕ (degrees)	Outside Diameter (in inches) at St. 4	St. 5	St. 6	St. 7	St. 8	St. 9	St. 10
0	10.765	10.729	10.730	10.705	10.735	10.750	10.787
22.5	10.765	10.735	10.720	10.725	10.710	10.741	10.797
45.0	10.738	10.700	10.690	10.717	10.685	10.705	10.759
67.5	10.738	10.677	10.671	10.690	10.664	10.677	10.700
90.0	10.700	10.680	10.672	10.680	10.660	10.690	10.681
112.5	10.713	10.680	10.675	10.695	10.694	10.716	10.732
135.0	10.735	10.695	10.685	10.707	10.715	10.728	10.762
157.5	10.758	10.703	10.713	10.740	10.737	10.745	10.807

Average O.D. = 10.716 in.

($Z_0 \geq 0$). Since a deliberate attempt was made to machine the ME-1 model to minimize thickness variations, this is probably a reasonable assumption.

For all three meshes, the elbow and its adjoining straight sections were modeled with flat plate finite elements (the NASTRAN element QUAD2) which have both membrane and bending stiffness. As indicated in Figure 1, one end was completely fixed, and the other end (where loads are applied) was connected to a stiff flange (which was assumed to be rigid in the finite element model).

The bulk of the NASTRAN data deck for each model was generated by a computer program called PIPELB, described briefly in the next section.

The finite element (QUAD2) used in these models yields stresses at element centroids. Hence, to facilitate comparison with experiment at the middle of the elbow ($\theta = 45°$), an odd number of elements was used in the longitudinal direction.

Figure 2 shows the Mesh A finite element model. This plot was generated using the Structural Analysis via Generalized Interactive Graphics (STAGING) system.[2]

The characteristics of the three meshes are summarized in Table 3. In all three cases, the element aspect ratios within the elbow were selected so as not to deviate significantly from unity, which is the optimum aspect ratio for the QUAD2 finite element.

THE DATA GENERATOR

The computer program PIPELB was written to generate NASTRAN data for THETA-degree elbows of ideal or non-ideal geometry adjoined on both sides by straight sections of arbitrary length. In addition to the GRID cards, which locate the finite element mesh points, the program also generates the plating (NASTRAN data card CQUAD2), pressure loading (PLOAD2), symmetry and other constraints (SPC), and flags for congruent elements (CNGRNT). As added conveniences, PIPELB will automatically generate the set of element identification numbers (ID's) for the mid-THETA elements which constitute the solution set for stresses; flexible spokes (CBAR) radiating from the centers of both elbow end-circles which facilitate the

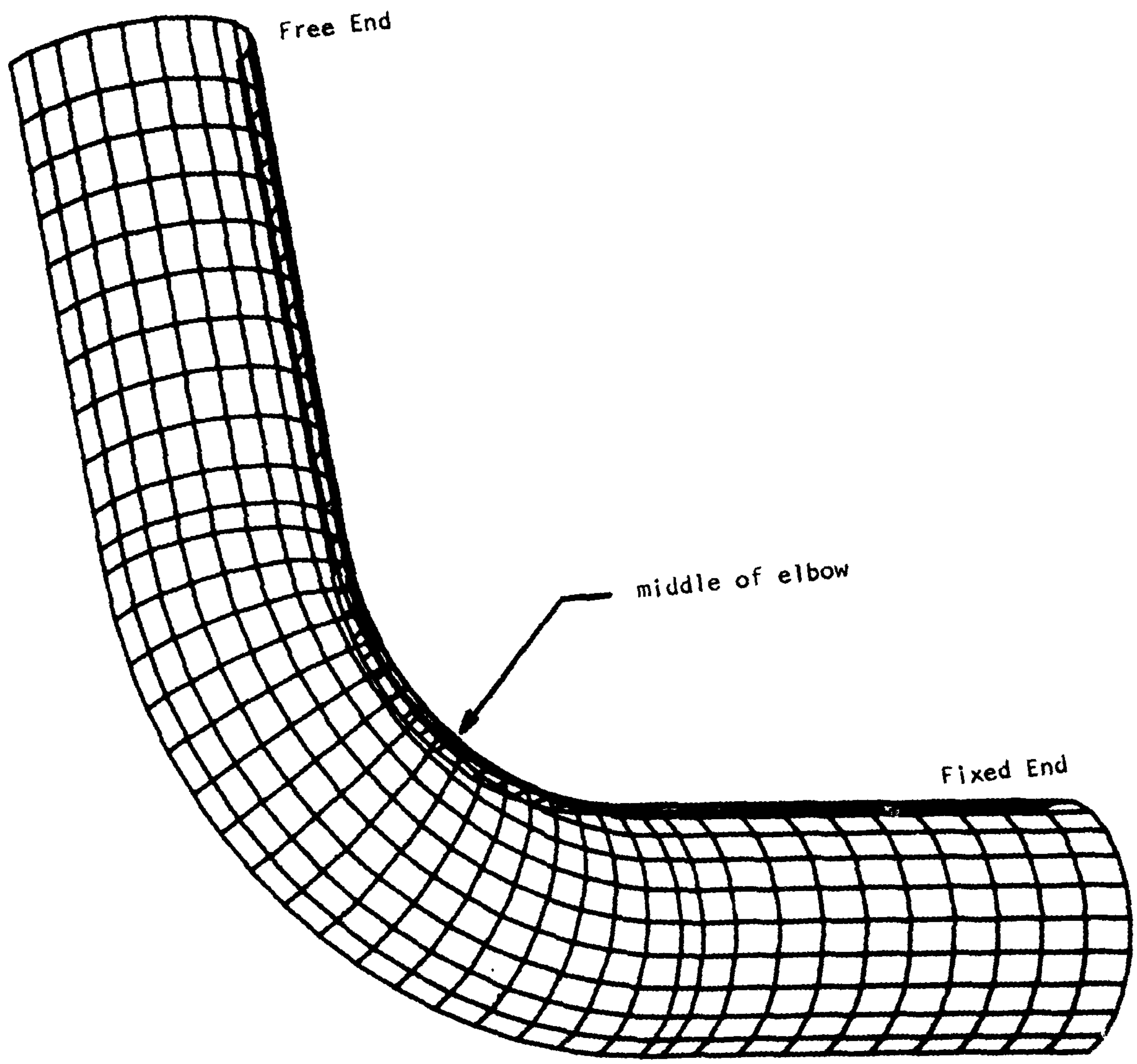


Figure 2 - Finite Element Model of Elbow (Mesh A)

TABLE 3 - SUMMARY OF FINITE ELEMENT ANALYSES

Structure Being Analyzed: Pipe Elbow ME-1 (See Figure 1)

Modeling and Computational Parameters	Mesh A	Mesh B	Mesh C
Ideal or actual geometry	ideal	ideal	actual
Mean radius of pipe	5.163 in.	5.163 in.	see Tables 1,2
Thickness of pipe	0.390 in.	0.390 in.	see Table 1
No. of elements in circumferential direction	12	18	12
No. of elements longitudinally spanning 90° elbow	17	27	17
No. of elements longitudinally spanning 21.0" straight section	11	16	11
No. of elements longitudinally spanning 20.5" straight section	11	16	11
Total number of elements	468	1062	468
Number of grid points	520	1140	520
Number of degrees of freedom	2745	6273	2745
Average matrix wavefront	79	116	79
NASTRAN CP time (CDC 6400)	949 sec.	2850 sec.	1339 sec.

computation of flexibility factors; a rigid element (CRIGD1) at the free (loaded) end of the pipe; and the end cap longitudinal load (FORCE) due to unit internal pressure.

The data generator defines grid locations within the elbow section in terms of a local cylindrical coordinate system (ID number 1 in Figure 1) defined by

$$\begin{aligned} R &= \mathrm{RBEND} - \mathrm{RPIPE} \cdot \cos\phi \\ T &= \theta_1 \\ Z &= \mathrm{RPIPE} \cdot \sin\phi \end{aligned} \tag{1}$$

where RBEND is the elbow bend radius measured to the pipe centerline, RPIPE is the mean pipe radius, ϕ is the angle spanning the pipe half-circumference, and θ_1 is the angle spanning the elbow arc of THETA degrees. (Other coordinate systems used in the NASTRAN data deck are defined in Figure 1.) The grid marking system defines the grid ID's as

$$\mathrm{GRID\ ID} = 1000 \cdot (500 + \mathrm{ITH}) + \mathrm{IPH} \tag{2}$$

where ITH and IPH are θ_1 and ϕ, respectively, rounded to the nearest integer. The element ID assigned to each quadrilateral is equal to the GRID ID that would be assigned for a node located at the element centroid.

For example, for Mesh A, the elbow was modeled with 17 elements covering the 90° elbow arc longitudinally (i.e., a spacing of 5.294°) and 12 elements covering 180° (i.e., a spacing of 15°) in the circumferential direction. Thus, for this mesh, point 51100 is at the intrados (the inside edge), 511090 is at the top, and 511180 is at the extrados (the outside edge) of the elbow, with all three points at θ_1 = 10.588°.

The shell was modeled with plate elements (NASTRAN data card CQUAD2). Symmetry constraints were applied with SPC's at ϕ = 0° and ϕ = 180°. An internal pressure loading was specified using a PLOAD2 card for each plate element, and the resultant longitudinal load at the closed free end (due to the pressure) was specified with a FORCE card. The inplane bending, out-of-plane bending, and torsion moment loads were applied at the rigid flange at the free end using MOMENT cards. All grid points at the fixed end were constrained in all six degrees of freedom.

Appendix A provides a listing of the card deck needed to create an UPDATE program library, compile source code, and catalog executable code for the data generator PIPELB.

Appendix B gives a listing of a typical card deck needed to execute the data generator and create a data file suitable for input to NASTRAN. The specific example used in Appendix B is for Mesh A. The result of executing this step is the NASTRAN data deck, which is listed in Appendix E. Various sections of this data deck have been labeled with comment cards, which have a $ in card column number one.

For Mesh C, which uses the measured geometry as listed in Tables 1 and 2, the data generator interpolates to obtain pipe thicknesses at element centroids and to obtain pipe radii at the grid points. This interpolation is performed within the generator in subroutine FIND. For Mesh C, each element has a unique thickness and hence a unique property card (PQUAD2).

SOLUTION SEQUENCE

The general computational approach is to perform the following steps:

<u>Step 1:</u> Compile the elbow data generator, and catalog an executable form of the program. See Appendix A.

<u>Step 2:</u> For the desired mesh, execute the generator, and create and store the NASTRAN data deck. See Appendix B.

<u>Step 3:</u> Using the data deck created in Step 2, execute NASTRAN and save (on a permanent file) the stresses at the desired location ($\theta_1 = 45°$). See Appendix C for a listing of control cards to accomplish this.

<u>Step 4:</u> Smooth the stress curves in preparation for plotting, storing the results. Figure 3 shows a typical plot of the type desired, where various stresses at the section $\theta_1 = 45°$ are plotted as a function of ϕ, the circumferential coordinate. As can be seen in Figure 3, the smoothing merely provides a more attractive display of the results. The smoothing in Figure 3 was obtained by using the B-spline[3] application subprogram CRVFIT.[4,5] See Appendix D for a listing of the deck to read the NASTRAN principal stresses and perform the smoothing.

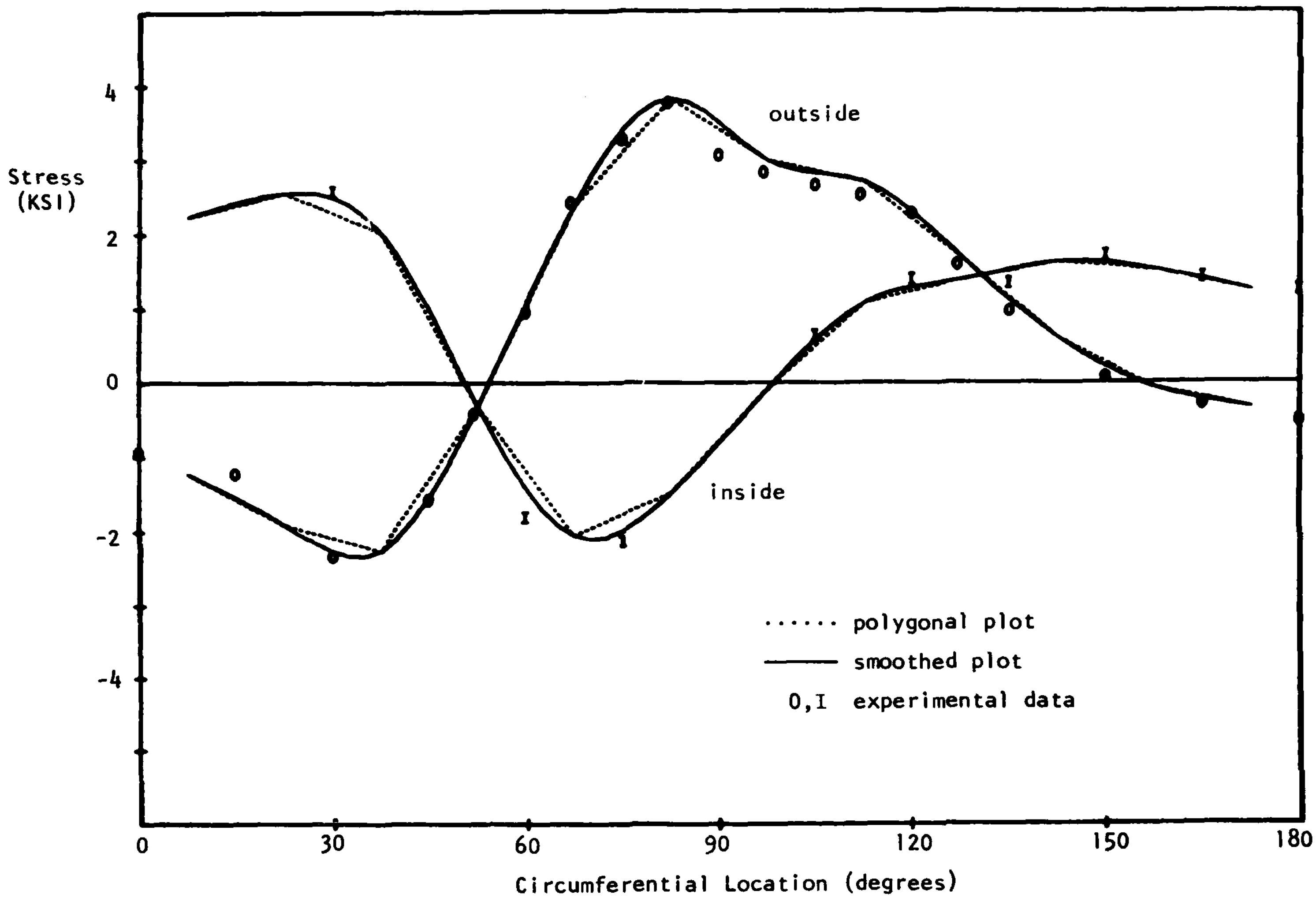


Figure 3 - Comparison of Polygonal and Smoothed Plots of Major Principal Stress at Middle of Elbow Due to Inplane Moment Load (Mesh A)

Step 5: Plot the smoothed results using the informally documented interactive computer graphics package PLOT QUICK developed by Mr. Melvin E. Haas of DTNSRDC (Code 1843).

FLEXIBILITY FACTORS

The finite element models also allow for the convenient determination of flexibility factors, which are of vital interest to piping systems designers. To avoid confusion, the term "flexibility factor," as used in this report, will be defined precisely. The flexibility factor k of a piping component is defined as the ratio of a relative rotation of that component to a nominal rotation:

$$k = \frac{\theta_{ab}}{\theta_{nom}} \tag{3}$$

where

θ_{ab} = rotation of end "a" of the piping component relative to end "b" of that component due to a moment loading M, and in the direction of M.

θ_{nom} = nominal rotation of an equal length of straight pipe due to the moment M.

For elbows, the nominal rotation is computed using simple beam theory, in which case one obtains

$$\theta_{nom} = \frac{ML}{EI} \tag{4}$$

for inplane and out-of-plane moments, and

$$\theta_{nom} = \frac{ML}{GJ} \tag{5}$$

for torsional moments, where

M = applied moment load

L = arc length of elbow

E = Young's modulus of material

G = shear modulus of material

I = moment of inertia of cross-section

J = torsional constant of cross-section (equal to the polar moment

of inertia for circular cross-sections)

For 90° elbows, $L = \pi R/2$, where R is the bend radius.

The determination of the relative rotation θ_{ab} from the finite element model is complicated by the fact that plane cross-sections do not remain plane after deformation, so that each point on the surface of the shell has a different rotation. However, an "average" rotation for a cross-section may be obtained by connecting very flexible beam spokes from each shell grid point to a new grid point located at the center of the circular cross-section. The rotation of this center point may be used as the average rotation for the cross-section. For Mesh A, the center point at Station 4 in Figure 1 is labeled 590500 (end "a") and at Station 10, 500500 (end "b").

Table 4 shows the details of the flexibility factor calculations for the three moment loads for Mesh A.

RESULTS AND DISCUSSION

Principal stresses were computed by NASTRAN at the middle of the elbow ($\theta_1 = 45°$) and compared to experimental results obtained at the Oak Ridge National Laboratory.[1] These stresses were computed for four separate loading conditions:

1) internal pressure of 75.53 psi
2) inplane bending moment of 32,660 in-lb
3) out-of-plane bending moment of 32,660 in-lb
4) torsional moment of 32,660 in-lb

Figures 4-11 compare the smoothed NASTRAN stress curves as computed using Meshes A, B, and C with the experimental data points. The major and minor principal stress results are presented on alternating figures for each of the four loading conditions. Note that placing more strain gauges on the outer surface than on the inner surface of the pipe wall resulted in a greater number of experimental data points there. Also, for selected experiments, some gauge results were missing.

The following conclusions may be drawn from Figures 4-11:

1. The NASTRAN results using Meshes A and B (both ideal geometry) are in good overall agreement with the experimental results. Although

TABLE 4 - FLEXIBILITY FACTORS FOR MESH A

Moment Load	θ_a (rad)	θ_b	$\theta_{ab} = \theta_b - \theta_a$	θ_{nom}	k
Inplane	1.32×10^{-4}	11.08×10^{-4}	9.76×10^{-4}	1.57×10^{-4}	6.2
Out-of-plane	1.78×10^{-4}	7.19×10^{-4}	5.41×10^{-4}	1.57×10^{-4}	3.4
Torsion	1.32×10^{-4}	6.79×10^{-4}	5.47×10^{-4}	2.04×10^{-4}	2.7

$$\text{flexibility factor} = k = \frac{\theta_{ab}}{\theta_{nom}}$$

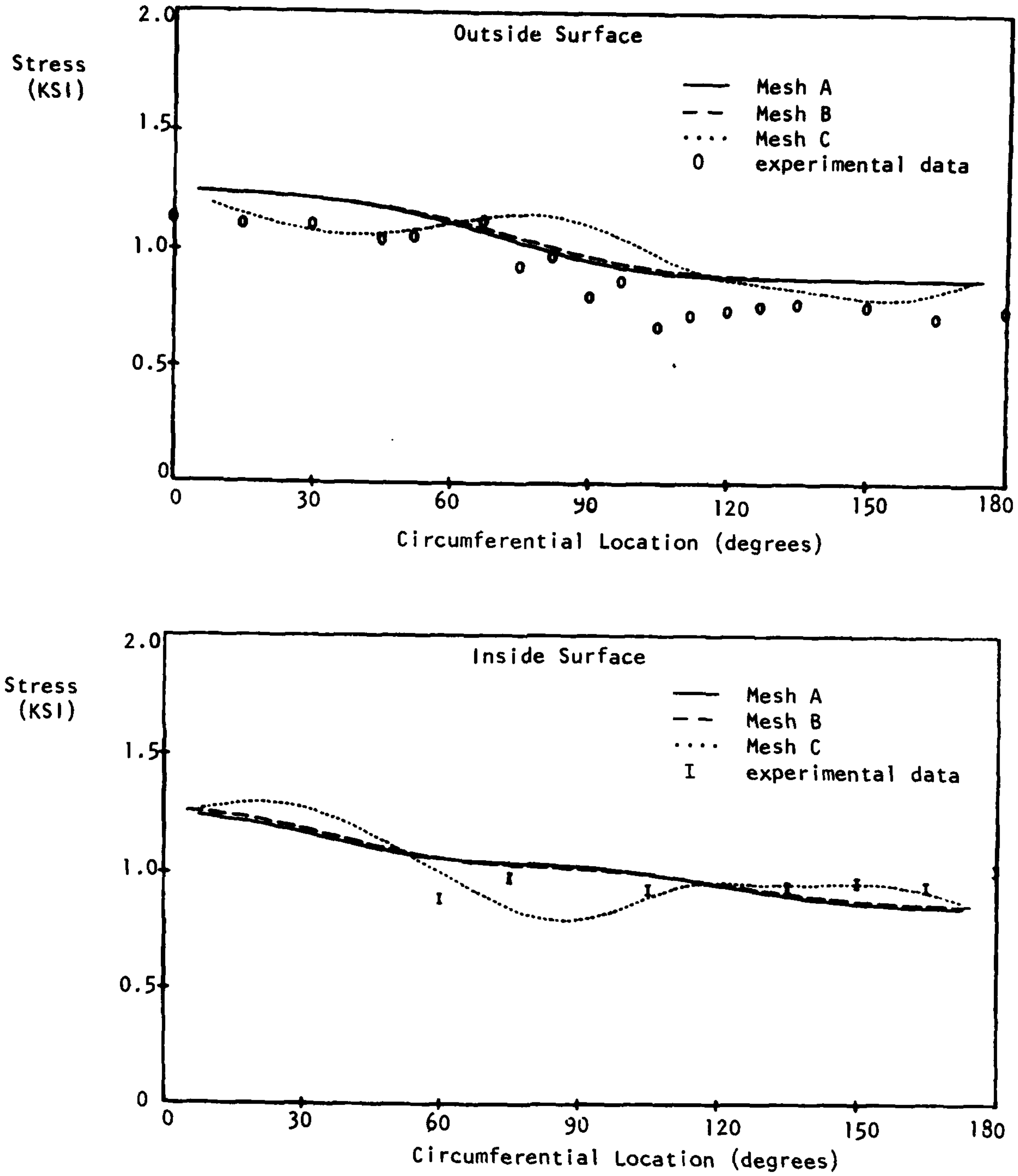


Figure 4 - Comparison of Computed and Experimental Stresses at Middle of Elbow - Major Principal Stress, Pressure Load

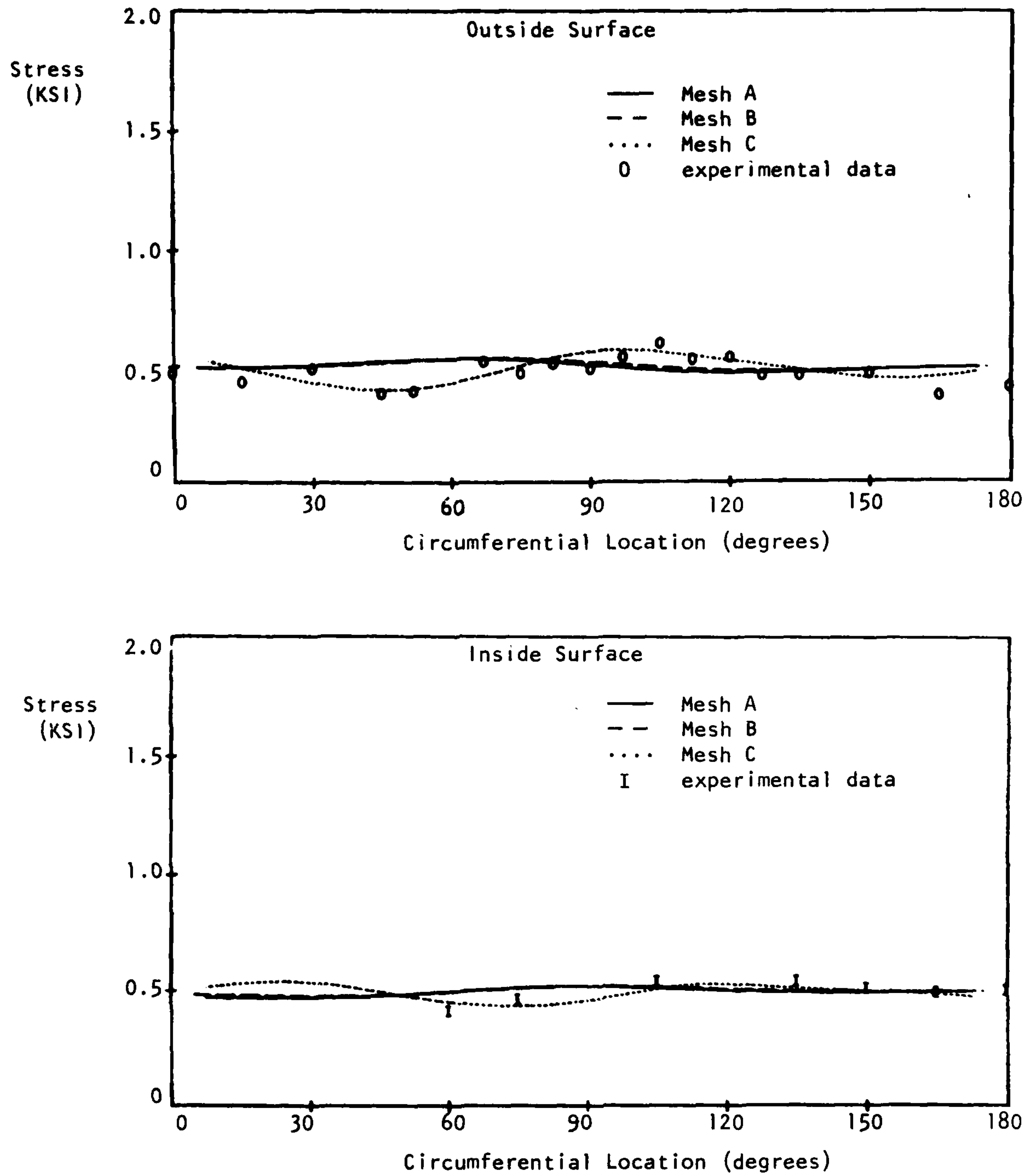


Figure 5 - Comparison of Computed and Experimental Stresses at Middle of Elbow - Minor Principal Stress, Pressure Load

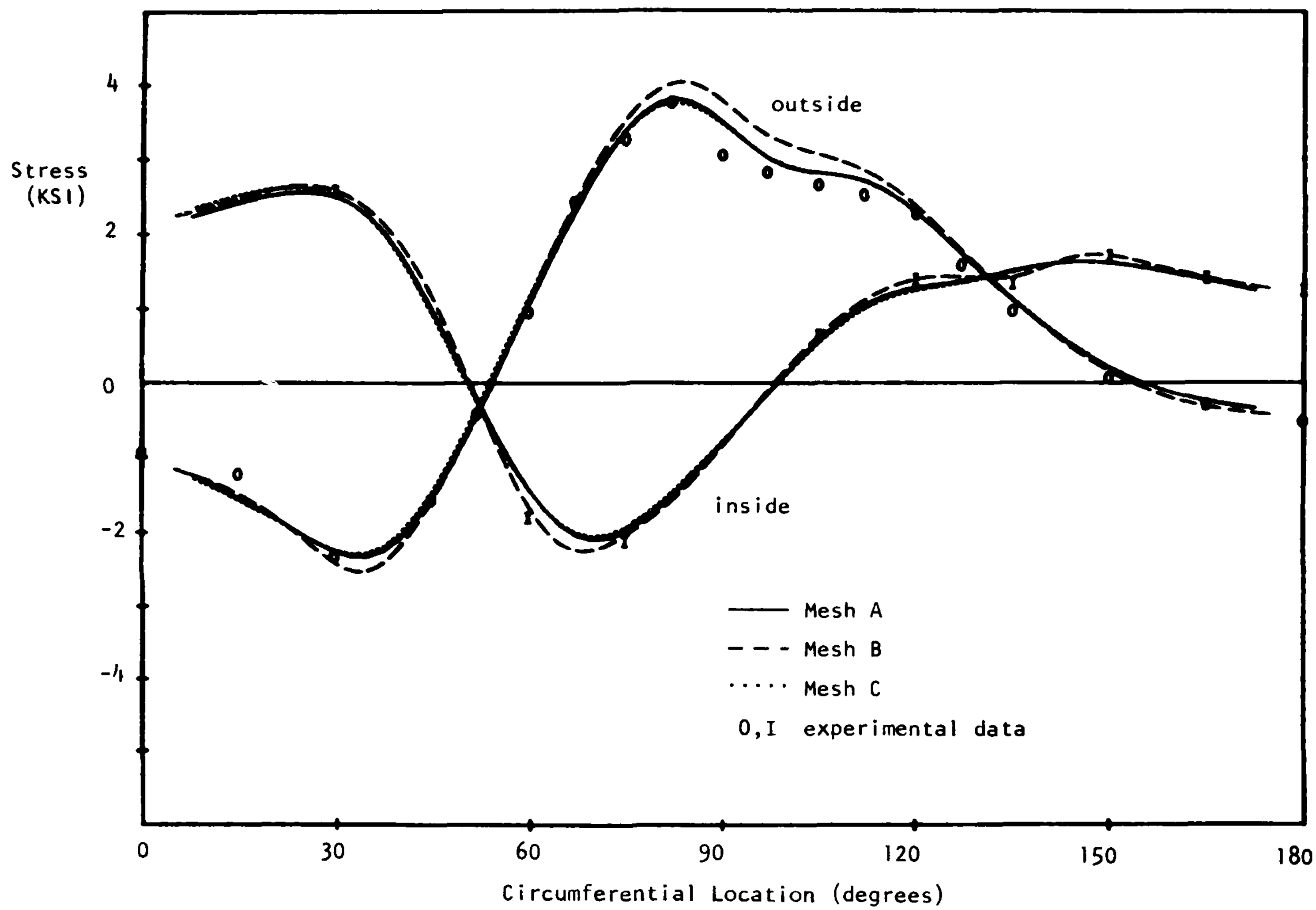


Figure 6 - Comparison of Computed and Experimental Stresses at Middle of Elbow - Major Principal Stress, Inplane Moment Load

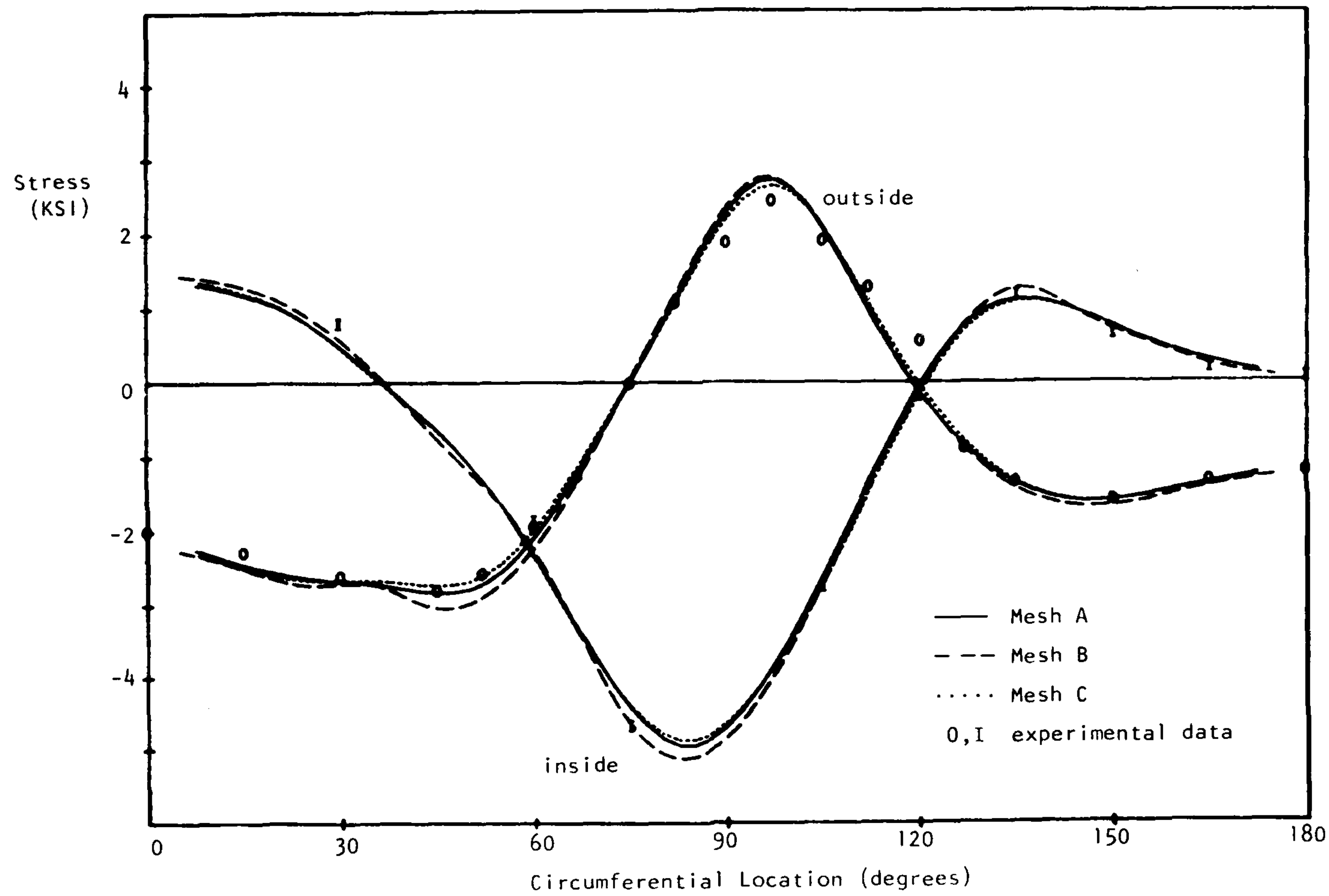


Figure 7 - Comparison of Computed and Experimental Stresses at Middle of Elbow - Minor Principal Stress, Inplane Moment Load

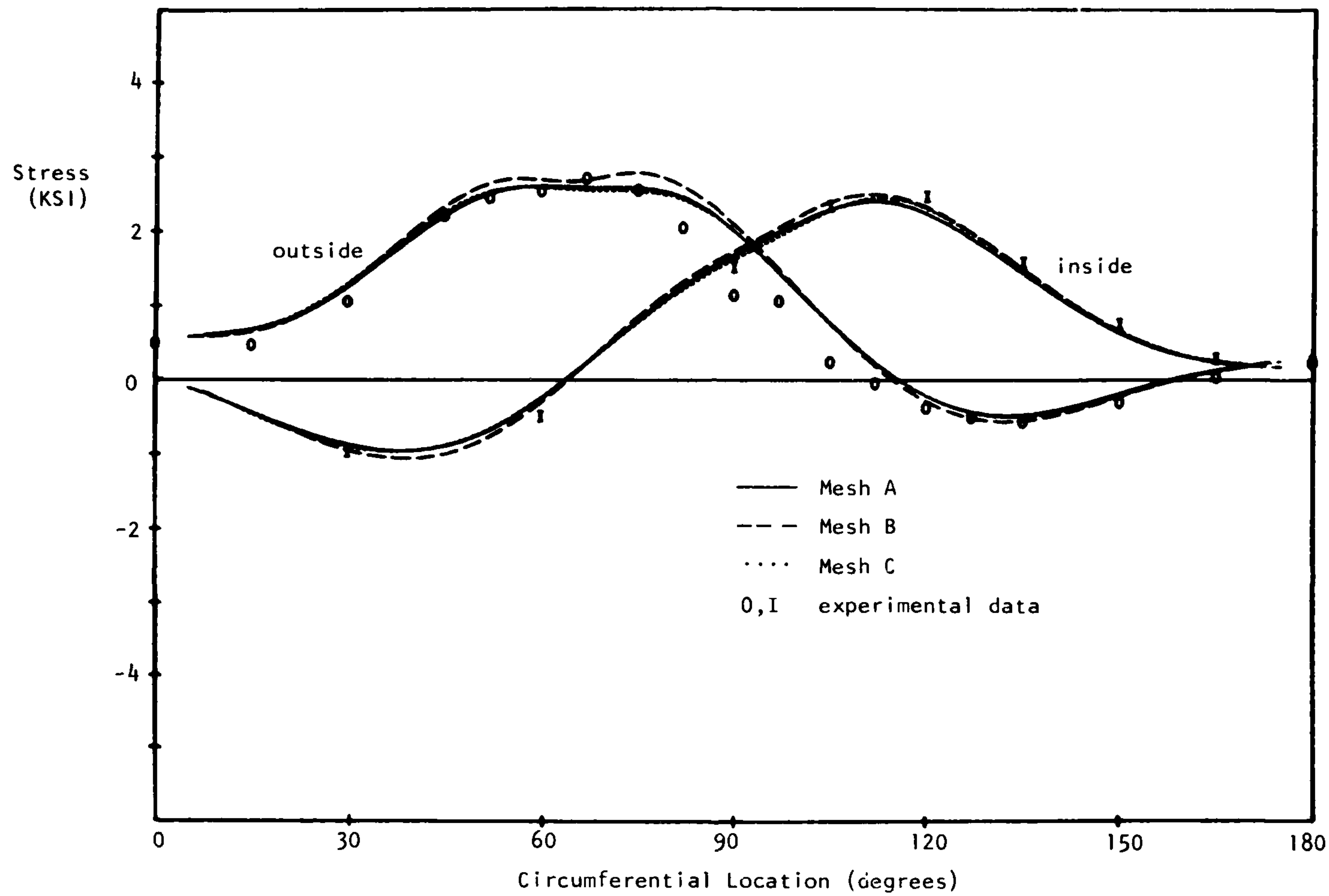


Figure 8 - Comparison of Computed and Experimental Stresses at Middle of Elbow - Major Principal Stress, Out-of-Plane Moment Load

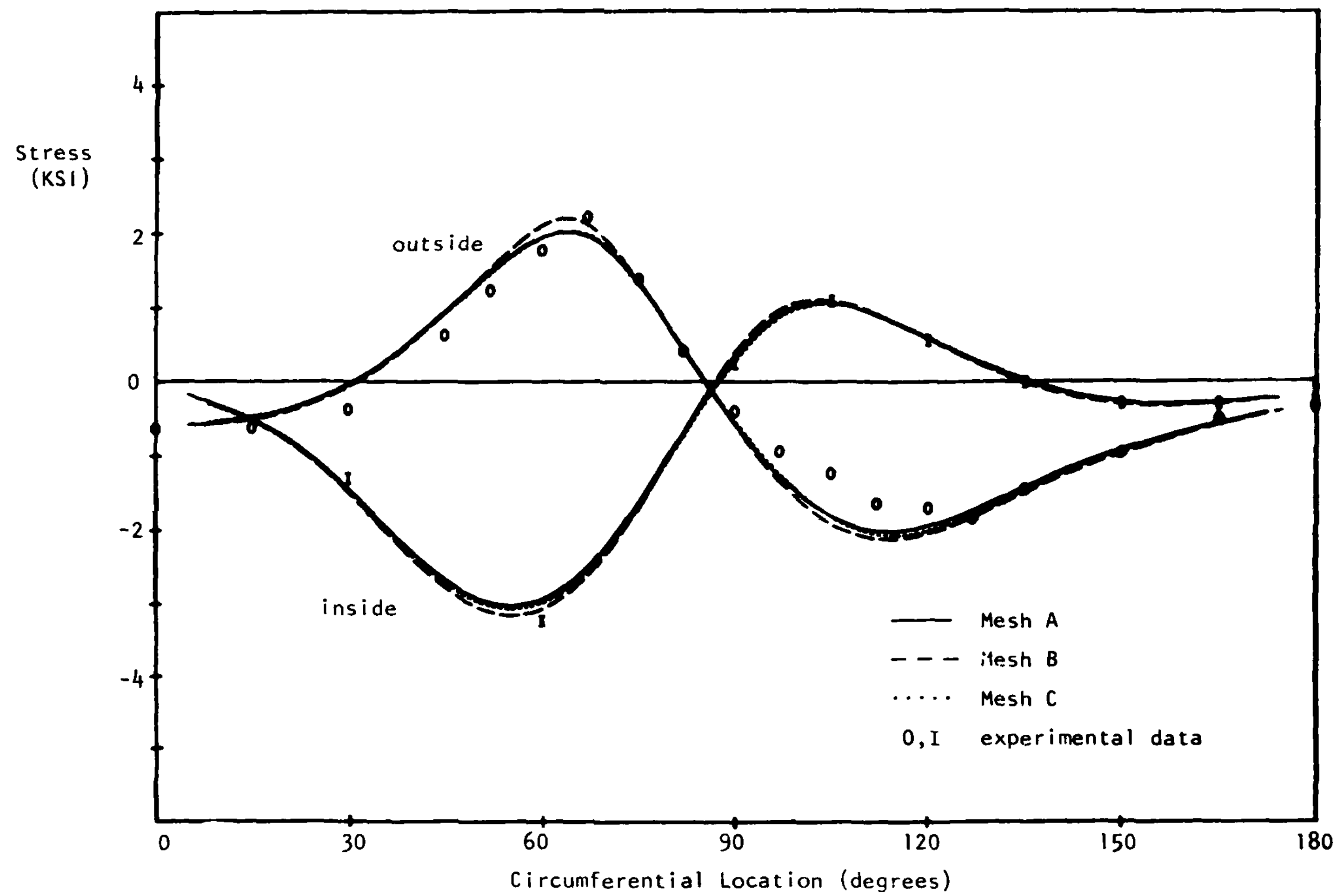


Figure 9 - Comparison of Computed and Experimental Stresses at Middle of Elbow - Minor Principal Stress, Out-of-Plane Moment Load

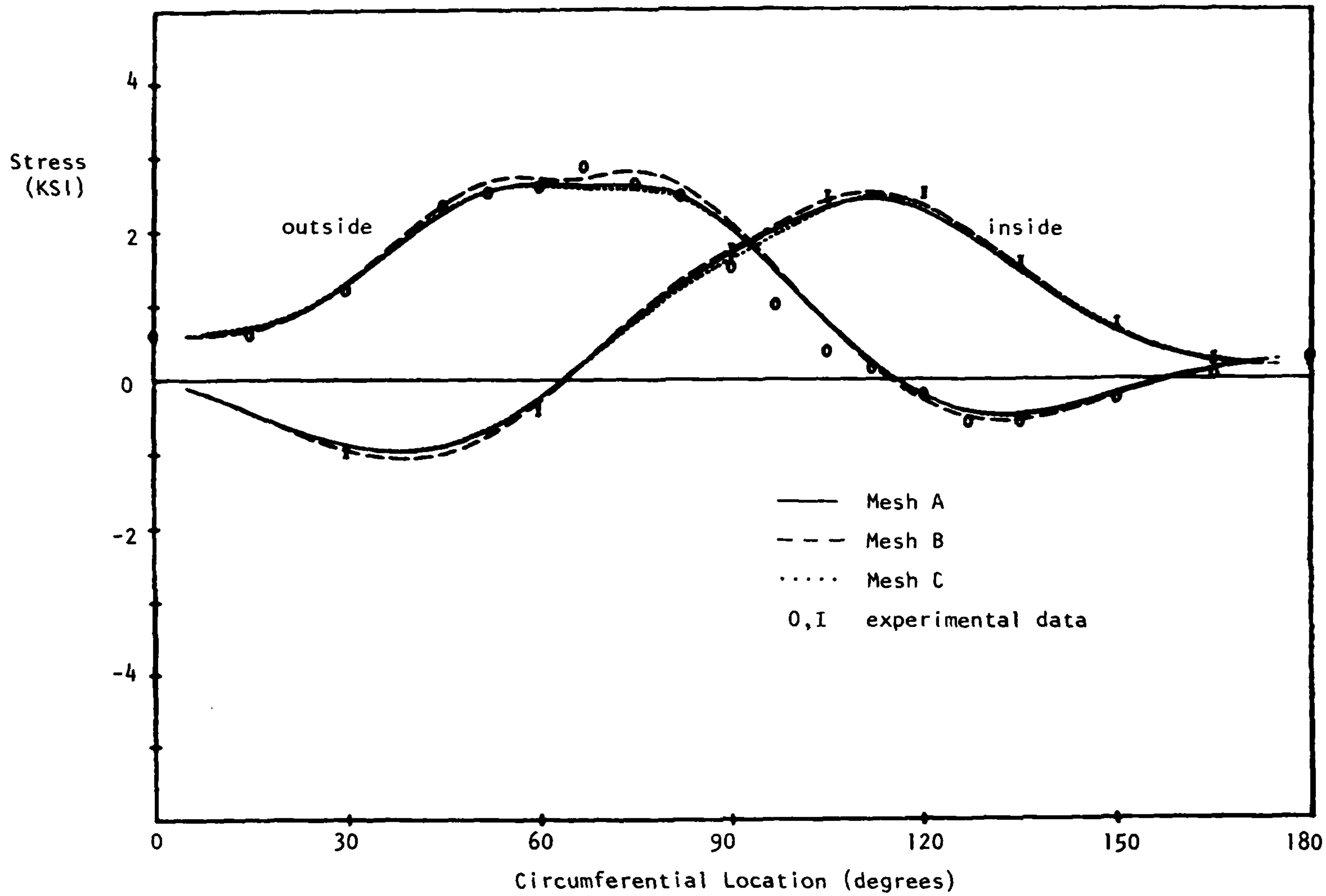


Figure 10 - Comparison of Computed and Experimental Stresses at Middle of Elbow - Major Principal Stress, Torsion Moment Load

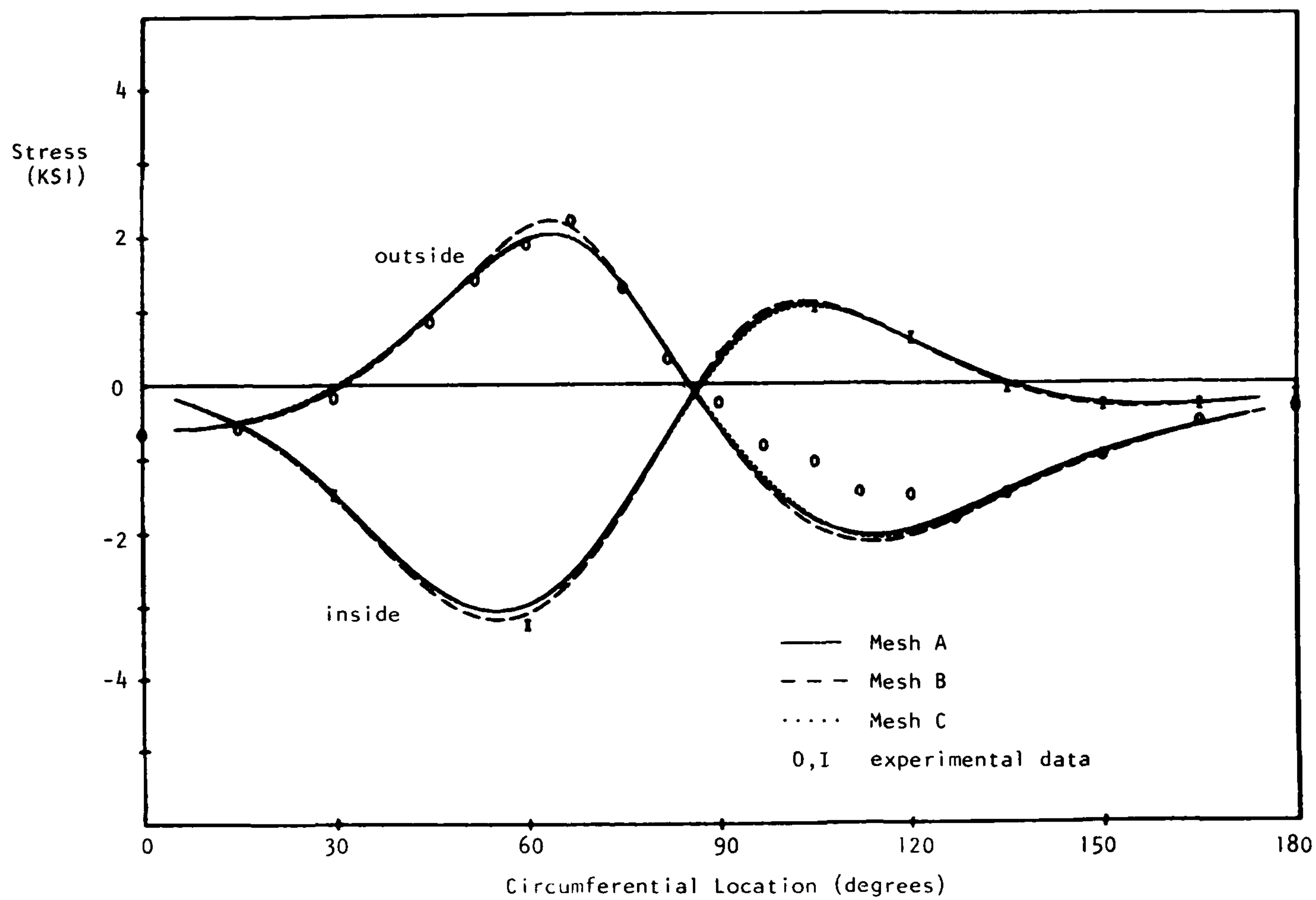


Figure 11 - Comparison of Computed and Experimental Stresses at Middle of Elbow - Minor Principal Stress, Torsion Moment Load

the coarser model (Mesh A) is non-conservative in that it underestimates (in absolute value) the stresses, its prediction of peak principal stresses is nevertheless excellent.

2. The Mesh C (actual geometry) results indicate that, except for internal pressure loading, the small variations in geometry shown in Tables 2 and 3 play an insignificant role in the stress computations. (The Oak Ridge researchers found in their more extensive experiments[1] that ovality in the pipe cross-section had a major influence on stresses only for pressure loading.)

3. When a large series of computer runs (e.g., a parameter study of pipe elbows) is contemplated, the gain in accuracy achieved with Mesh B (which has a fifty percent finer mesh spacing than Mesh A) would probably not be cost-effective. (The CDC 6400 computer charge at DTNSRDC was $292 for Mesh B compared to $99 for Mesh A.)

ACKNOWLEDGMENTS

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APPENDIX A

Listing of Deck to Create UPDATE Program Library, Compile Source Code, and Catalog Executable Code for Elbow Data Generator

```
(JOB CARD)
(CHARGE CARD)
REQUEST,NEWPL,*PF.
UPDATE,F,C,N.
CATALOG,NEWPL,PFNAME1,ID=XXXX.
REQUEST,LGO,*PF.
FTN,OPT=1,R=3,PL=5000000,I=COMPILE.
CATALOG,LGO,PFNAME2,ID=XXXX.
7/8/9 EOR    **** SOURCE DECK FOR DATA GENERATOR FOLLOWS ****
*DECK ELB
      PROGRAM PIPELB(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE8,TAPE9,
     - TAPE10,TAPE11,TAPE12,TAPE13,TAPE14,TAPE15,TAPE16,TAPE17,TAPE18,
     - TAPE19,TAPE20,TAPE21,TAPE22,TAPE23,TAPE24,TAPE25,TAPE26,TAPE27)
C
C     DATA GENERATOR FOR NASTRAN STRESS  ANALYSIS OF A PIPE HAVING
C          THETA DEGREE ELBOW AND STRAIGHT SECTIONS
C     INPUT GENERATION INCLUDES FINITE ELEMENT PLATING (CQUAD2,GRID),
C        CONGRUENCY (CNGRNT) AND PRESSURE LOADING (PLOAD2) FOR ELEMENTS,
C        AND GRID POINT CONSTRAINTS (SPC)
C
C     MEL MARCUS,DTNSRDC 1843,JAN 1979
C
      DIMENSION IDUM(8),ICNGR(35,24)
      INTEGER ASET(24)
      COMMON/A/THETA,NPH1,DPH,RPIPS,PIDS,LOADID,PLOAD
      COMMON/B/NX,NY,TABX(9),TABY(7),TABF(9,7,2)
      INTEGER         EID,PIDS,PID,SID,G(4)
      INTEGER CPC,CDC
      DATA PI/3.141592654/
C
    1 FORMAT (1H1)
    3 FORMAT (10F8.3)
    4 FORMAT (24I3)
    8 FORMAT (8A10)
    9 FORMAT (8HCBAR     ,4I8,3F8.1,I8)
   10 FORMAT (8HCNGRNT   ,2I8)
   11 FORMAT (8HCQUAD2   ,6I8)
   12 FORMAT (8HGRID     ,2I8,F8.4,F8.3,F8.4,2I8)
   15 FORMAT (8HPLOAD2   ,I8,F8.3,I8)
   16 FORMAT (8HPQUAD2   ,2I8,F8.3)
   17 FORMAT (8HSPC      ,3I8)
   26 FORMAT (8HSET 1 =  ,8(I6,2H, )/(8X, 8(I6,2H, )))
   27 FORMAT (8X,I6)
   28 FORMAT (8HFORCE    ,3I8,F8.4,3F8.0)
C
C
C
C     PRESENTED BELOW ARE THE 4 READ ITEMS WHICH OCCUR IN PIPELB
C     ALSO INDICATED  ARE THE 4 READ ITEMS WHICH FOLLOW
C           IN 2 CALLS TO SUBROUTINE STRATE
C
C
C     PHI=PORTION OF PIPE CIRCUMFERENCE MODELED, DEGREES
C     THETA=PORTION OF ELBOW ARC MODELED ,DEGREES
C
      PHI=180.
      READ  (5,3) THETA
      WRITE (6,3) THETA
C
C     NPHI=NUMBER OF ELEMENTS IN PHI DIRECTION
C     NTHETA=NUMBER OF ELEMENTS IN THETA DIRECTION (COORD SYSTEM CPC)
C
      READ  (5,4) NPHI,NTHETA
```

```
      WRITE (6,4) NPHI,NTHETA
C
C     RBEND=BEND RADIUS MEASURED TO PIPE CENTERLINE
C     RPIPS,PIDS=NOMINAL VALUES OF PIPE RADIUS ,THICKNESS (PROPERTY ID)
C
      PIDS=200
      READ  (5,3) RBEND,RPIPS
      WRITE (6,3) RBEND,RPIPS
C
C     THIS ITEM CONTAINS A SINGLE READ (BLANK CARD)
C           OR MULTIPLE (3+NF*NY) READS
C     DEPENDING ON WHETHER NF=0 (IDEAL ELBOW)
C               OR NF=2 (VARIABLE RADIUS AND THICKNESS)
C
C     NX,NY=NUMBERS OF PHI,THETA-DIRECTION VALUES (TABX,TABY)
C             AT WHICH TABULATED VALUES OF
C     RADIUS  AND THICKNNESS (NF=2) ARE SPECIFIED FOR ELBOW
C
C     IF NF=0, THEN NOMINAL VALUES OF OF PIPE RADIUS
C             AND THICKNESS ARE USED THROUGHOUT
C     OTHERWISE, VARIABLE RADIUS AND THICKNESS VALUES ARE COMPUTED
C         FOR THETA-DIR VALUES BETWEEN TABY(1) AND TABY(NY) DEGREES
C             WITH NOMINAL VALUES USED ELSEWHERE
C
      READ  (5,4) NX,NY,NF
      WRITE (6,4) NX,NY,NF
      IF (NF.EQ.0) GO TO 45
      READ  (5,3) (TABX(I),I=1,NX)
      WRITE (6,3) (TABX(I),I=1,NX)
      READ  (5,3) (TABY(I),I=1,NY)
      WRITE (6,3) (TABY(I),I=1,NY)
      DO 40 K=1,NF
      DO 40 J=1,NY
      READ  (5,3) (TABF(I,J,K),I=1,NX)
      WRITE (6,3) (TABF(I,J,K),I=1,NX)
   40 CONTINUE
   45 CONTINUE
C
C     THE 2 ITEMS READ NEXT ARE TRIGGERED BY "CALL STRATE(1)"
C     THE ITEMS TO BE READ ARE DESCRIBED ATOP SUBROUTINE STRATE
C
C     THE LAST 2 ITEMS READ ARE TRIGGERED BY "CALL STRATE(2)"
C     THE ITEMS TO BE READ ARE DESCRIBED ATOP SUBROUTINE STRATE
C
C
C
      CPC=1
      CDC=1
      MID=45
      LOADID=21
      PLOAD=-1.
C
      DPH=PHI/NPHI
      DTH=THETA/NTHETA
      NPH1=NPHI+1
      NTH1=NTHETA+1
      IHTH=NTH1/2
C
C     END CAP LOAD DUE TO UNIT INTERNAL PRESSURE - 27
C
      CAPLD=.5*NPHI*RPIPS*RPIPS*SIN(DPH *PI/180.)
      WRITE (27,28) LOADID,200500,3,CAPLD,0.,0.,-1.
C
```

```
C
C     GENERATE FE PLATING FOR STRAIGHT SECTION  (TOP)
C     CHECK SUBROUTINE STRATE FOR INPUT TO BE READ IN
      CALL STRATE (1)
C
C
C     GENERATE FE PLATING FOR ELBOW
C
C
      TH=0.
      IBASE=500000
C
C
      DO 200 I=1,NTH1
      PID=PIDS
      RPIPE=RPIPS
      ITH=TH+.5
      INEXT=TH+DTH+.5
      IMOVE=1000*(INEXT-ITH)
      PH=0.
      ID=IBASE
C
C     DEFINE MYTHICAL CENTER POINTS ALONG ELBOW
C
      NBARS=0
      IDCEN=ID+500
C
C
      DO 150 J=1,NPH1
C
C     SPOKES (CBAR - 9) CONVERGE TO MYTHICAL CENTERS AT ELBOW ENDS
C
      IF (I.NE.1.AND.I.NE.NTH1) GO TO 50
      NBARS=NBARS+1
      IDBAR=IDCEN+NBARS
      IF (J.EQ.1.OR .J.EQ.NPH1) GO TO 52
      WRITE (9,9)IDBAR,PIDS+2,ID,IDCEN,0.,1.,0.,1
      GO TO 50
   52 WRITE (9,9)IDBAR,PIDS+1,ID,IDCEN,0.,1.,0.,1
   50 CONTINUE
C
      IPH=PH+.5
      INEXT=PH+DPH+.5
      JMOVE=INEXT-IPH
C
C     POSSIBLY INTERPOLATE FOR PIPE RADIUS
C
      IF (NF.EQ.0) GO TO 60
      IF (TH.GT.TABY(NY)) GO TO 62
      CALL FIND (PH,TH,1,THICK)
      CALL FIND (PH,TH,2,OD)
      RPIPE=.5*(OD-THICK)
      IREG=NTH1
      GO TO 64
   60 IREG=1
      GO TO 64
   62 IREG=I
   64 IREG1=IREG+1
C
C
C     GRID FOR ELBOW - 13
C
C
```

```
C      ELBOW MODELED IN CYLINDRICAL R,T,Z COORD SYSTEM CPC
C             IN WHICH T IS PORTION OF THETA
C
       ANG=PH*PI/180.
       R=RBEND-RPIPE*COS(ANG)
       Z=RPIPE*SIN(ANG)
       WRITE (13,12) ID,CPC,R,TH,Z,CDC
       IF (J.EQ. NPH1) GO TO  20
       IF (I.EQ. NTH1) GO TO  115
C
       ICEN=TH+.5*DTH+.5
       JCEN=PH+.5*DPH+.5
       EID=1000*ICEN+JCEN+500000
       IF (I.EQ.IHTH) ASET(J)=EID
C
C      ASSIGNING   CONGRUENCY
C
       ICNGR(I,J)=EID
C
C      POSSIBLY INTERPOLATE FOR PIPE THICKNESS
C      IF SO , GENERATE PROPERTY CARD - 16
C
       IF (NY.EQ.0) GO TO 80
       IF (TH.GT.TABY(NY)) GO TO 80
       PID=EID
       PC=PH+.5*DPH
       TC=TH+.5*DTH
       CALL FIND (PC,TC,1,THICK)
       WRITE (16,16) PID,MID,THICK
   80  CONTINUE
C
C      CQUAD2 FOR ELBOW - 11
C
       G(1)=ID
       G(2)=G(1)+IMOVE
       G(3)=G(2)+JMOVE
       G(4)=G(3)-IMOVE
       WRITE (11,11) EID,PID,(G(L),L=1,4)
C
C      PLOAD2 FOR QUADS - 15
C
       WRITE (15,15) LOADID,PLOAD,EID
  115  IF (J.NE.1) GO TO 100
C
C      SPC FOR ELBOW - 18,21
C            SYM B.C. AT PHI=0,180 - 18
C      ANTI- SYM B.C. AT PHI=0,180 - 21
C
   20  SID=71
       L=345
       WRITE (18,17) SID,ID,L
       SID=72
       L=126
       WRITE (21,17) SID,ID,L
C
  100  ID=ID+JMOVE
       PH=PH+DPH
C
C
  150  CONTINUE
C
C
       IBASE=IBASE+IMOVE
```

```
      TH =TH +DTH
  200 CONTINUE
C
C
C     CNGRNT (THETA DIRECTION ONLY) FOR ELBOW - 10
C
      IF (IREG .GE.NTHETA) GO TO 210
      DO 205 J=1,NPHI
      DO 205 I=IREG1,NTHETA
  205 WRITE (10,10) ICNGR(IREG,J),ICNGR(I,J)
  210 CONTINUE
C
C     SOLUTION SET FOR CASE CONTROL - 26
C
      WRITE (26,26) (ASET(J),J=1,NPHI)
      WRITE (26,27) 999999
C
C
C     GENERATE FE PLATING FOR STRAIGHT SECTION (BOTTOM)
C     CHECK SUBROUTINE STRATE FOR INPUT TO BE READ IN
      CALL STRATE (2)
C
C
C
      WRITE (6,1)
      DO 1000 I=9,27
      REWIND I
  910 READ (I,8) (IDUM(K),K=1,8)
      IF (EOF(I).NE.0) GO TO 920
      WRITE(8,8) (IDUM(K),K=1,8)
      GO TO 910
  920 REWIND I
 1000 CONTINUE
      REWIND 8
C
C
      STOP
      END
      SUBROUTINE STRATE (IFLAG)
C
C     GENERATE FE PLATING FOR STRAIGHT SECTION
C     IFLAG=1,2 INDICATES PORTION ABOVE,BELOW ELBOW
C
      DIMENSION        ZS(25),IZDZCH(6),KOUNT( 5),IJCNGR(5,500)
      COMMON/A/THETA,NPH1,DPH,RPIPS,PIDS,LOADID,PLOAD
      INTEGER CPS,CDS,EID,PIDS,PID,SID,G(4)
C
    2 FORMAT (I8,9F8.2/(10F8.2))
    4 FORMAT (24I3)
   10 FORMAT (8HCNGRNT  ,2I8)
   11 FORMAT (8HCQUAD2  ,6I8)
   12 FORMAT (8HGRID    ,2I8,F8.4,F8.3,F8.4,2I8)
   15 FORMAT (8HPLOAD2  ,I8,F8.3,I8)
   17 FORMAT (8HSPC     ,3I8)
   25 FORMAT (8HCRIGD1  ,3I8)
C
C
C     STRAIGHT SECTION MODELED IN CYLINDRICAL R,T,Z COORD SYSTEM CPS
C             IN WHICH Z IS DISTANCE ALONG STRAIGHT EDGE
C              ( Z=0 AT POINTS OF CURVATURE/TANGENCY )
C
C
C
```

```
C      NZS1=NUMBER OF GRID POINTS IN Z DIRECTION
C      ZS(I)=Z-COORDS OF THE NZS1 PTS IN COORD SYSTEM CPS
C
C      FOR IFLAG=1, VALUES BEGIN AT Z=-L1 AND END AT Z=0
C      FOR IFLAG=2, VALUES BEGIN AT Z=0 AND END AT Z=L2
C            WHERE L1,L2 ARE PIPE LENGTHS ABOVE,BELOW ELBOW
C
       READ  (5,2) NZS1,(ZS(I),I=1,NZS1)
       WRITE (6,2) NZS1,(ZS(I),I=1,NZS1)
C
C      NDZCHS=NUMBER OF CHANGES IN DZ=ZS(I+1)-ZS(I)
C      IZDZCH(K)=VALUES OF I  ,I=1 TO NZS1, AT WHICH DZ CHANGES
C         (CONVENTION IS TO SPECIFY I=1 AS A CHANGE)
C
       READ  (5,4) NDZCHS,(IZDZCH(K),K=1,NDZCHS)
       WRITE (6,4) NDZCHS,(IZDZCH(K),K=1,NDZCHS)
C
C
C
C      SET UP CONGRUENCY SETS
C
       IBOOM=0
       NSETS=  NDZCHS
       DO 650 I=1,NSETS
   650 KOUNT(I)=0
C
C
       IF (IFLAG.EQ.2) GO TO 20
       CPS=3
       CDS=3
       NTPGRD=12
       NTPSYM=17
       NTPAS=20
       ILIM=NZS1-1
       IBASE=(500-10*ILIM)*1000
       IRIGID=IBASE
       GO TO 30
    20 CPS=2
       CDS=2
       NTPGRD=14
       NTPSYM=19
       NTPAS=22
       ILIM=NZS1
       IBASE=(500+THETA)*1000
    30 RPIPE=RPIPS
       PID=PIDS
C
C
       DO 400 I=1,ILIM
       IMOVE=10000
       PH=0.
       ID=IBASE
C
C
       DO 350 J=1,NPH1
       IPH=PH+.5
       INEXT=PH+DPH+.5
       JMOVE=INEXT-IPH
C
C      RIGID ELEMENTS AT FREE END - 25
C
       IF (I.NE.1.OR.IFLAG.NE.1) GO TO 27
       WRITE (25,25) J+1,200500,IRIGID
```

```
      IRIGID=IRIGID+JMOVE
   27 CONTINUE
C
C
C     GRID FOR STRAIGHT SECTION - NTPGRD
C
      IF (IFLAG.EQ.2.AND.I.EQ.1) GO TO 202
      NT=NTPGRD
      WRITE (NT,12) ID,CPS,RPIPE,PH,ZS(I),CDS
  202 IF (J.EQ. NPH1) GO TO 220
      IF (IFLAG.EQ.2.AND.I.EQ.ILIM) GO TO 215
C
      EID=ID
      IF (IFLAG.EQ.1.AND.I.EQ.ILIM) GO TO 204
      IF (IFLAG.EQ.2.AND.I.EQ.1)    GO TO 204
C
C     TESTING FOR AND ASSIGNING CONGRUENCY
C
      IBOOM=IBOOM+1
      IZDZCH(NDZCHS+1)=NZS1
      DO 700 K=1,NDZCHS
      NSET=0
      IZ1=IZDZCH(K  )-1
      IZ2=IZDZCH(K+1)-1
      IF (I.GT.IZ1.AND.I.LE.IZ2) NSET=K
      IF (NSET.EQ.0) GO TO 700
      IF (IBOOM.EQ.1) NSET1=NSET
      NSETS=NSET
      KOUNT(NSET)=KOUNT(NSET)+1
      KNT=KOUNT(NSET)
      IJCNGR(NSET,KNT) =EID
  700 CONTINUE
C
C     CQUAD2 FOR STRAIGHT SECTION - 11
C
  204 G(1)=ID
      G(2)=G(1)+IMOVE
      G(3)=G(2)+JMOVE
      G(4)=G(3)-IMOVE
      WRITE (11,11) EID,PID,(G(L),L=1,4)
C
C     PLOAD2 FOR QUADS - 15
C
      WRITE (15,15) LOADID,PLOAD,EID
      IF (IFLAG.EQ.1.AND.I.EQ.1) GO TO 300
  215 IF (J.EQ.1) GO TO 220
      IF (IFLAG.EQ.2.AND.I.EQ.ILIM) GO TO 225
      GO TO 300
C
C     SPC FOR STRAIGHT SECTION - NTPSYM,NTPAS,23,24
C           SYM B.C. AT PHI=0,180 - NTPSYM
C     ANTI- SYM B.C. AT PHI=0,180 - NTPAS
C     ELIM ZERO DOF  AT PHI=0,180 - 23
C     CONSTRAIN FIXED END         - 24
C
  220 IF (I.EQ.1) GO TO 300
      SID=71
      L=246
      NT=NTPSYM
      WRITE (NT,17) SID,ID,L
      SID=72
      L=135
      NT=NTPAS
```

```
      WRITE (NT,17) SID,ID,L
      SID=80
      L=4
      WRITE (23,17) SID,ID,L
      IF (IFLAG.EQ.2.AND.I.EQ.ILIM) GO TO 225
      GO TO 300
  225 SID=85
      L=123456
      WRITE (24,17) SID,ID,L
C
  300 ID=ID+JMOVE
      PH=PH+DPH
C
C
C
  350 CONTINUE
      IBASE=IBASE+IMOVE
C
C
  400 CONTINUE
C
C
C     CNGRNT (BOTH DIRECTIONS) FOR STRAIGHT SECTION - 10
C
      DO 405 K=NSET1,NSETS
      KNT=KOUNT(K)
      DO 405 L=2,KNT
  405 WRITE (10,10) IJCNGR(K,1),IJCNGR(K,L)
C
C
      RETURN
      END
      SUBROUTINE FIND (X,Y,K,FXY)
C
C     INTERPOLATE FOR FUNCTIONAL VALUES WHICH ARE
C     TABULATED FOR BOTH X AND Y TABULATED VALUES
C
C     K INDICATES FUNCTION BEING CONSIDERED
C
      DIMENSION FX(7)
      COMMON/B/NX,NY,TABX(9),TABY(7),TABF(9,7,2)
C
      DO 10 J=2,NY
      IF (TABY(J).GT.Y) GO TO 15
   10 CONTINUE
      J2=NY
      GO TO 20
   15 J2=J
   20 J1=J2-1
C
      DO 30 I=2,NX
      IF (TABX(I).GT.X) GO TO 35
   30 CONTINUE
      I2=NX
      GO TO 40
   35 I2=I
   40 I1=I2-1
C
      XRAT=(X-TABX(I1))/(TABX(I2)-TABX(I1))
      DO 50 J=J1,J2
   50 FX(J)=TABF(I1,J,K)+XRAT*(TABF(I2,J,K)-TABF(I1,J,K))
C
      YRAT=(Y-TABY(J1))/(TABY(J2)-TABY(J1))
      FXY=FX(J1)+YRAT*(FX(J2)-FX(J1))
C
      RETURN
      END
6/7/8/9 EOF
```

APPENDIX B

Listing of Deck to Execute Elbow Data Generator and Create NASTRAN Input Data File for Mesh A

```
(JOB CARD)
(CHARGE CARD)
ATTACH,PIPELB,PFNAME2,ID=XXXX.
PIPELB.
REQUEST,NEWPL,*PF.
UPDATE,F,C,N,D.
CATALOG,NEWPL,PFNAME3,ID=XXXX.
COPYSBF,COMPILE.
7/8/9 EOR    **** INPUT DATA (MESH A) FOR DATA GENERATOR FOLLOWS ****
90.
 12 17
15.0     5.163
(BLANK CARD)
      12 -21.    -18.5     -16.5     -14.5     -12.5     -10.5     -8.5      -6.5      -4.5
-2.5      -1.       0.
  4  1  2 10 11
      12 0.      1.        2.5       4.5       6.5       8.5       10.5      12.5      14.5
16.5     18.5     20.5
  3  1  2  3
7/8/9 EOR    **** INPUT DECK TO UPDATE FOLLOWS ****
*DECK DATA
NASTRAN CONFIG=6,FILES=(PLT2,NPTP,OPTP,INPT)
ID PIPE,ELBOW
APP DISP
SOL 1,0
TIME 25
$SEQUENCE YES
$GRID=525
$CONFIG=6
CEND
TITLE =STRESS ANALYSIS OF ELBOW ME-1  (ORNL-TM-4834)
MAXLINES=500000
*READ TAPE26
DISP=ALL
STRESS(PRINT,PUNCH)=1
SPCFORCE=ALL
$
$        SUBCASES HAVING SAME B.C. ARE GROUPED TOGETHER
$           TO AVOID UNNECESSARY MATRIX DECOMPOSITIONS
$
SUBCASE 1
   SUBTITLE=UNIT PRESSURE LOAD
   LABEL=SYM B.C.
   LOAD=21
   SPC=91
   OLOAD=ALL
   STRESS=1
SUBCASE 2
   SUBTITLE=UNIT IN-PLANE (Z) MOMENT
   LABEL=SYM B.C.
   LOAD=22
   SPC=91
   OLOAD=ALL
   STRESS=1
SUBCASE 3
   SUBTITLE=UNIT OUT-OF-PLANE (X) MOMENT
   LABEL=ANTI-SYM B.C.
   LOAD=23
   SPC=92
   OLOAD=ALL
   STRESS=1
SUBCASE 4
   SUBTITLE=UNIT TORSIONAL (Y) MOMENT
```

```
   LABEL=ANTI-SYM B.C.
   LOAD=24
   SPC=92
   OLOAD=ALL
   STRESS=1
SUBCOM 21
   SUBTITLE=PRESSURE LOAD OF 75.53 PSI
   SUBSEQ=75.53,0.,0.,0.
SUBCOM 22
   SUBTITLE=IN-PLANE MOMENT OF 32660 IN-LB
   SUBSEQ=0.,-32660.,0.,0.
SUBCOM 23
   SUBTITLE=OUT-OF-PLANE MOMENT OF 32660 IN-LB
   SUBSEQ=0.,0.,32660.,0.
SUBCOM 24
   SUBTITLE=   TORSIONAL MOMENT OF 32660 IN-LB
   SUBSEQ=0.,0.,0.,32660.
$
$
$       STRUCTURE     ...PIPE (RPIPE=5.163) CONSISTS OF
$                        90 DEGREE ELBOW (RBEND=15.0)
$                        ADJOINED BY STRAIGHT SECTIONS
$
$       SYMMETRY      ...IMPOSED AT PIPE HALF-CIRCUM (PHI=0,180)
$
$       COORD SYSTEMS...(ELBOW) R=RBEND-RPIPE*COS(PHI)
$                               T=THETA, (THETA=0,90 AT P.C.,P.T.)
$                               Z=RPIPE*SIN(PHI)
$
$       COORD SYSTEMS...(STRAIGHT SEC) R=RPIPE
$                                      T=PHI
$                                (TOP) Z=-DISTANCE FROM P.C.
$                             (BOTTOM) Z=DISTANCE FROM P.T.
$
$       NODAL VALUES ...(ELBOW)        ID=1000*(500+ITH)+IPH
$                               WHERE ITH ARE ROUNDED NODAL VALUES OF THETA
$                                     IPH ARE ROUNDED NODAL VALUES OF PHI
$
$                       (STRAIGHT SEC)
$                                (TOP) ID=1000*(500-10*(J-I))+IPH
$                                                         I=0,1,2,...,J-1
$                             (BOTTOM) ID=1000*(590+10*I)+IPH
$                                                      I=1,2,...,K
$                       WHERE J IS NO. OF Z-INTERVALS SUBDIVIDING TOP SEC
$                             K IS NO. OF Z-INTERVALS SUBDIVIDING BOT SEC
$
$
$
BEGIN BULK
$
$       SPOKES AT ELBOW ENDS CONVERGE TO MYTHICAL CENTER POINTS
$
*READ TAPE9
$
$       ELEMENT CONGRUENCY...(ELBOW)        THETA DIRECTION ONLY
$                            (STRAIGHT SEC) BOTH DIRECTIONS
$
*READ TAPE10
$
$                 ELBOW DEFINED IN COORD SYSTEM 1
$       STRAIGHT BOTTOM  DEFINED IN COORD SYSTEM 2
$       STRAIGHT TOP     DEFINED IN COORD SYSTEM 3
$       ORNL CARTESIAN SYSTEM IS NO. 4
```

```
$
CORD2C  1       0       0.      0.      0.      0.      0.      1.      +COR1
+COR1   1.      0.      0.
CORD2C  2       0       0.      15.     0.      -1.     15.     0.      +COR2
+COR2   0.      14.     0.
CORD2C  3       0       15.     0.      0.      15.     1.      0.      +COR3
+COR3   14.     0.      0.
CORD2R  4       0       0.      0.      0.      0.      0.      -1.     +COR4
+COR4   1.      0.      0.
$
$       FINITE ELEMENT PLATING
$
*READ TAPE11
$
$       RIGID CONNECTION FOR FREE  (LOADED) END OF PIPE
$
CRIGD1  1       200500  100500
*READ TAPE25
$
$       END CAP LOAD DUE TO UNIT INTERNAL PRESSURE
$
*READ TAPE27
$
$       GRID POINTS
$
$       MYTHICAL CENTER POINT 1 UNIT BEYOND FREE END OF PIPE
$
GRID    100500  0       15.0    -22.0   0.      4
$
$       MYTHICAL CENTER POINT AT FREE END OF PIPE
$
GRID    200500  0       15.0    -21.0   0.      4
$
$       STRAIGHT SECTION ABOVE THETA=0
$
*READ TAPE12
$
$       MYTHICAL CENTER POINT AT THETA=0 END OF ELBOW
$             (EQUIV TO ORIGIN OF COORD SYS 3)
$
GRID    500500  0       15.0    0.      0.      4
$
$       ELBOW POINTS
$
*READ TAPE13
$
$       MYTHICAL CENTER POINT AT THETA=90 END OF ELBOW
$             (EQUIV TO ORIGIN OF COORD SYS 2)
GRID    590500  0       0.      15.     0.      4
$
$       STRAIGHT SECTION BELOW THETA=90
$
*READ TAPE14
$
MAT1    45      2.9+7           0.3     7.324-4                         STEEL
$
$       BENDING MOMENTS APPLIED AT FREE END
$
MOMENT  22      200500  0       0.50    0.      0.      1.
MOMENT  23      200500  0       0.50    1.      0.      0.
MOMENT  24      200500  0       0.50    0.      1.      0.
$
PBAR    201     45      1.0-6   1.0-9   1.0-9   2.0-9
```

```
PBAR    202     45      2.0-6   2.0-9   2.0-9   4.0-9
$
$       INTERNAL PRESSURE LOADING FOR PIPE
$
*READ TAPE15
$
PQUAD2  200     45      0.390
$
$       SPC...(SID=71)        SYM B.C. AT MIDPLANE CUTTING PIPE CIRCUM
$
SPC     71      200500  345
*READ TAPE17
SPC     71      500500  345
*READ TAPE18
SPC     71      590500  345
*READ TAPE19
$
$               (SID=72)  ANTI-SYM B.C. AT MIDPLANE CUTTING PIPE CIRCUM
$
SPC     72      200500  126
*READ TAPE20
SPC     72      500500  126
*READ TAPE21
SPC     72      590500  126
*READ TAPE22
$
$       ELIMINATION OF ZERO STIFFNESS DOF
$
*READ TAPE23
$
$       CONSTRAIN FIXED END
$
*READ TAPE24
$
SPCADD  91      71      80      85
SPCADD  92      72      80      85
ENDDATA
6/7/8/9 EOF
```

APPENDIX C

Listing of Deck to Execute NASTRAN and Save Stresses at Middle of Elbow

```
(JOB CARD)
(CHARGE CARD)
LIMIT,13000.
MAP,OFF,
ATTACH,OLDPL,PFNAME3,ID=XXXX.
UPDATE,F,C=DATA,N,D.
ATTACH,NASTRAN.
REQUEST,PUN,*PF.
RFL,160000.
BEGIN,NASTRAN,NASTRAN,,DATA,,PUN.
CATALOG,PUN,PFNAME4,ID=XXXX.
7/8/9 EOR   **** UPDATE CORRECTIONS (IF ANY) FOLLOW ****
6/7/8/9 EOF
```

APPENDIX D

Listing of Deck to Smooth Principal Stresses and Create Solution File in PLOT QUICK Format

```
(JOB CARD)
(CHARGE CARD)
ATTACH,TAPE9,PFNAME4,ID=XXXX.
REQUEST,TAPE10,*PF.
ATTACH,PROD,461PRODUCTS,ID=CSYS.
ATTACH,BSPLNLB,ID=CAMK.
LIBRARY,PROD,BSPLNLB.
LOADLDR.
FTN.
LOADLDR.
LGO.
CATALOG,TAPE10,PFNAME5,ID=XXXX.
7/8/9 EOR    **** SOURCE DECK FOLLOWS *****
      PROGRAM PREPLT(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE9,TAPE10)
C
C
C
C     THIS PROGRAM READS (TAPE9) NASTRAN-GENERATED ELBOW STRESS OUTPUT,
C     SELECTS FROM IT A SOLUTION SUBSET,
C     SMOOTHS THIS SOLUTION SET,
C     AND THEN SCALES + SAVES THE ORIGINAL AND SMOOTHED SOLUTION SETS,
C     EACH IN A PLOTQUICK (INTERACTIVE PLOTTING) FORMAT ON TAPE10
C
C
C     CARD INPUT CONSISTS OF NPTS,THE NO. OF ELMTS IN CIRCUMFER DIREC,
C     FOLLOWED BY A SHORT AND LONG NAME, TITS AND TITL, RESPECTIVELY,
C     FOR EACH OF THE 34 CURVES WHICH GIVE,
C     IN AN ALTERNATING (UNSMOOTHED AND SMOOTHED) PATTERN,
C      THE CIRCUMFERENTIAL COORDINATES, FOLLOWED BY A CONSECUTIVE STRING
C     OF MAJOR-OUTER,MINOR-OUTER,MAJOR-INNER,MINOR-INNER STRESS VALUES
C     FOR EACH OF THE 4 DIFFERENT LOADING CONDITIONS
C
C     MEL MARCUS, DTNSRDC 1843, FEB 1979
C
C
C
      DIMENSION Z(19),TITS(1),TITL(8)
      DIMENSION GPVAL(16),X(18),   NSEEK(4),C1(2,18),C2(2,103),Y(4,4,18)
      COMMON WORK(3000)
C
    1 FORMAT(1H1)
    2 FORMAT(13F6.2)
    3 FORMAT(12G11.4)
    4 FORMAT(8A10)
    5 FORMAT(1X,8A10)
    7 FORMAT(26I3)
    8 FORMAT(I10,8X,3E18.6/(18X,3E18.6,8X))
    9 FORMAT(2I3,E16.8)
C
      NLOADS=4
      NSKIP=7
      NVALUS=16
      NS=4
      NSEEK(1)=6
      NSEEK(2)=7
      NSEEK(3)=14
      NSEEK(4)=15
C
      READ  (5,9) NPTS
      WRITE (6,9) NPTS
      DANG=180./NPTS
      N1=6*(NPTS-1)+1
C
```

```
C
C
      WRITE (6,1)
      DO  20 K=1,NLOADS
      WRITE (6,9) K
C
      DO 10 I=1,NSKIP
   10 READ (9,4) TITS(1)
C
      DO 20 I=1,NPTS
      READ (9,8)  ID,(GPVAL(M),M=1,NVALUS)
      WRITE (6,8) ID,(GPVAL(M),M=1,NVALUS)
      X(I)=(I-.5)*DANG
C
      DO 20 J=1,NS
      N=NSEEK(J)
   20 Y(K,J,I)=GPVAL(N)
C
C
C
      SCFAC=.001
C
      WRITE (6,1)
      KOUNT=0
      DO 100 K=1,NLOADS
      DO 100 J=1,NS
C
      DO 30 I=1,NPTS
      C1(1,I)=X(I)
   30 C1(2,I)=Y(K,J,I)
C
      CALL CRVFIT(C1,2,NPTS,1,1.0,3,0,1.E-6,N1,0,WORK,3000,C2,RMS,IFAIL)
C
      IF (K.NE.1.OR.J.NE.1) GO TO 40
      KOUNT=KOUNT+1
      WRITE (6,7) KOUNT
      READ  (5,4) TITS(1)
      WRITE (6,5) TITS(1)
      WRITE (10)  TITS(1)
      READ  (5,4) (TITL(I),I=1,8)
      WRITE (6,5) (TITL(I),I=1,8)
      WRITE (10)  (TITL(I),I=1,8)
      WRITE (6,3) (C1(1,I),I=1,NPTS)
      WRITE (10)  (C1(1,I),I=1,NPTS)
      KOUNT=KOUNT+1
      WRITE (6,7) KOUNT
      READ  (5,4) TITS(1)
      WRITE (6,5) TITS(1)
      WRITE (10)  TITS(1)
      READ  (5,4) (TITL(I),I=1,8)
      WRITE (6,5) (TITL(I),I=1,8)
      WRITE (10)  (TITL(I),I=1,8)
      WRITE (6,3) (C2(1,I),I=1,N1)
      WRITE (10)  (C2(1,I),I=1,N1)
   40 CONTINUE
C
      KOUNT=KOUNT+1
      WRITE (6,7) KOUNT
      READ  (5,4) TITS(1)
      WRITE (6,5) TITS(1)
      WRITE (10)  TITS(1)
      READ  (5,4) (TITL(I),I=1,8)
      WRITE (6,5) (TITL(I),I=1,8)
```

```
      WRITE (10)  (TITL(I),I=1,8)
      WRITE (6,3) (C1(2,I)*SCFAC,I=1,NPTS)
      WRITE (10)  (C1(2,I)*SCFAC,I=1,NPTS)
      KOUNT=KOUNT+1
      WRITE (6,9) KOUNT,IFAIL,RMS
      READ  (5,4) TITS(1)
      WRITE (6,5) TITS(1)
      WRITE (10)  TITS(1)
      READ  (5,4) (TITL(I),I=1,8)
      WRITE (6,5) (TITL(I),I=1,8)
      WRITE (10)  (TITL(I),I=1,8)
      WRITE (6,3) (C2(2,I)*SCFAC,I=1,N1)
      WRITE (10)  (C2(2,I)*SCFAC,I=1,N1)
C
  100 CONTINUE
C
C
C
      END
7/8/9 EOR   **** INPUT DATA (MESH A) FOLLOWS *****
 12
PHI-U
PIPE CIRCUMFERENCE (DEGREES)
PHI
PIPE CIRCUMFERENCE (DEGREES)
PRES-UOMJR
NASTRAN MAJOR STRESS AT OUTER STATION 7 DUE TO PRESSURE LOAD
PRES-NOMJR
NASTRAN MAJOR STRESS AT OUTER STATION 7 DUE TO PRESSURE LOAD
*********** SHORT AND LONG NAMES FOR 30 MORE CURVES FOLLOW ************
6/7/8/9 EOF
```

APPENDIX E

Listing of NASTRAN Input Data File
for Mesh A

```
NASTRAN CONFIG=6,FILES=(PLT2,NPTP,OPTP,INPT)                                      DATA     2
ID PIPE,ELBOW                                                                     DATA     3
APP DISP                                                                          DATA     4
SOL 1,0                                                                           DATA     5
TIME 25                                                                           DATA     6
$SEQUENCE YES                                                                     DATA     7
$GRID=525                                                                         DATA     8
$CONFIG=6                                                                         DATA     9
CEND                                                                              DATA    10
TITLE =STRESS ANALYSIS OF ELBOW ME-1  (ORNL-TM-4834)                              DATA    11
MAXLINES=500000                                                                   DATA    12
SET 1 = 545008, 545023, 545038, 545053, 545068, 545083, 545098, 545113,           DATA    13
        545128, 545143, 545158, 545173,                                           DATA    14
        999999                                                                    DATA    15
DISP=ALL                                                                          DATA    16
STRESS(PRINT,PUNCH)=1                                                             DATA    17
SPCFORCE=ALL                                                                      DATA    18
$                                                                                 DATA    19
$       SUBCASES HAVING SAME B.C. ARE GROUPED TOGETHER                            DATA    20
$          TO AVOID UNNECESSARY MATRIX DECOMPOSITIONS                             DATA    21
$                                                                                 DATA    22
SUBCASE 1                                                                         DATA    23
   SUBTITLE=UNIT PRESSURE LOAD                                                    DATA    24
   LABEL=SYM B.C.                                                                 DATA    25
   LOAD=21                                                                        DATA    26
   SPC=91                                                                         DATA    27
   OLOAD=ALL                                                                      DATA    28
   STRESS=1                                                                       DATA    29
SUBCASE 2                                                                         DATA    30
   SUBTITLE=UNIT IN-PLANE (Z) MOMENT                                              DATA    31
   LABEL=SYM B.C.                                                                 DATA    32
   LOAD=22                                                                        DATA    33
   SPC=91                                                                         DATA    34
   OLOAD=ALL                                                                      DATA    35
   STRESS=1                                                                       DATA    36
SUBCASE 3                                                                         DATA    37
   SUBTITLE=UNIT OUT-OF-PLANE (X) MOMENT                                          DATA    38
   LABEL=ANTI-SYM B.C.                                                            DATA    39
   LOAD=23                                                                        DATA    40
   SPC=92                                                                         DATA    41
   OLOAD=ALL                                                                      DATA    42
   STRESS=1                                                                       DATA    43
SUBCASE 4                                                                         DATA    44
   SUBTITLE=UNIT TORSIONAL (Y) MOMENT                                             DATA    45
   LABEL=ANTI-SYM B.C.                                                            DATA    46
   LOAD=24                                                                        DATA    47
   SPC=92                                                                         DATA    48
   OLOAD=ALL                                                                      DATA    49
   STRESS=1                                                                       DATA    50
SUBCOM 21                                                                         DATA    51
   SUBTITLE=PRESSURE LOAD OF 75.53 PSI                                            DATA    52
   SUBSEQ=75.53,0.,0.,0.                                                          DATA    53
SUBCOM 22                                                                         DATA    54
```

```
   SUBTITLE=IN-PLANE MOMENT OF 32660 IN-LB                                DATA     55
   SUBSEQ=0.,-32660.,0.,0.                                                DATA     56
SUBCOM 23                                                                 DATA     57
   SUBTITLE=OUT-OF-PLANE MOMENT OF 32660 IN-LB                            DATA     58
   SUBSEQ=0.,0.,32660.,0.                                                 DATA     59
SUBCOM 24                                                                 DATA     60
   SUBTITLE=   TORSIONAL MOMENT OF 32660 IN-LB                            DATA     61
   SUBSEQ=0.,0.,0.,32660.                                                 DATA     62
$                                                                         DATA     63
$                                                                         DATA     64
$       STRUCTURE     ...PIPE (RPIPE=5.163) CONSISTS OF                   DATA     65
$                        90 DEGREE ELBOW (RBEND=15.0)                     DATA     66
$                        ADJOINED BY STRAIGHT SECTIONS                    DATA     67
$                                                                         DATA     68
$       SYMMETRY      ...IMPOSED AT PIPE HALF-CIRCUM (PHI=0,180)          DATA     69
$                                                                         DATA     70
$       COORD SYSTEMS...(ELBOW) R=RBEND-RPIPE*COS(PHI)                    DATA     71
$                               T=THETA, (THETA=0,90 AT P.C.,P.T.)        DATA     72
$                               Z=RPIPE*SIN(PHI)                          DATA     73
$                                                                         DATA     74
$       COORD SYSTEMS...(STRAIGHT SEC) R=RPIPE                            DATA     75
$                                      T=PHI                              DATA     76
$                                (TOP) Z=-DISTANCE FROM P.C.              DATA     77
$                             (BOTTOM) Z=DISTANCE FROM P.T.               DATA     78
$                                                                         DATA     79
$       NODAL VALUES ...(ELBOW)          ID=1000*(500+ITH)+IPH            DATA     80
$                               WHERE ITH ARE ROUNDED NODAL VALUES OF THETA  DATA  81
$                                     IPH ARE ROUNDED NODAL VALUES OF PHI DATA     82
$                                                                         DATA     83
$                       (STRAIGHT SEC)                                    DATA     84
$                                (TOP) ID=1000*(500-10*(J-I))+IPH         DATA     85
$                                                 I=0,1,2,....,J-1        DATA     86
$                             (BOTTOM) ID=1000*(590+10*I)+IPH             DATA     87
$                                               I=1,2,....,K              DATA     88
$                       WHERE J IS NO. OF Z-INTERVALS SUBDIVIDING TOP SEC DATA     89
$                             K IS NO. OF Z-INTERVALS SUBDIVIDING BOT SEC DATA     90
$                                                                         DATA     91
$                                                                         DATA     92
$                                                                         DATA     93
BEGIN BULK                                                                DATA     94
$                                                                         DATA     95
$       SPOKES AT ELBOW ENDS CONVERGE TO MYTHICAL CENTER POINTS           DATA     96
$                                                                         DATA     97
CBAR     500501    201  500000  500500    0.0     1.0     0.0       1     DATA     98
CBAR     500502    202  500015  500500    0.0     1.0     0.0       1     DATA     99
CBAR     500503    202  500030  500500    0.0     1.0     0.0       1     DATA    100
CBAR     500504    202  500045  500500    0.0     1.0     0.0       1     DATA    101
CBAR     500505    202  500060  500500    0.0     1.0     0.0       1     DATA    102
CBAR     500506    202  500075  500500    0.0     1.0     0.0       1     DATA    103
CBAR     500507    202  500090  500500    0.0     1.0     0.0       1     DATA    104
CBAR     500508    202  500105  500500    0.0     1.0     0.0       1     DATA    105
CBAR     500509    202  500120  500500    0.0     1.0     0.0       1     DATA    106
CBAR     500510    202  500135  500500    0.0     1.0     0.0       1     DATA    107
CBAR     500511    202  500150  500500    0.0     1.0     0.0       1     DATA    108
```

```
CBAR      500512    202  500165  500500   0.0   1.0   0.0    1        DATA  109
CBAR      500513    201  500180  500500   0.0   1.0   0.0    1        DATA  110
CBAR      590501    201  590000  590500   0.0   1.0   0.0    1        DATA  111
CBAR      590502    202  590015  590500   0.0   1.0   0.0    1        DATA  112
CBAR      590503    202  590030  590500   0.0   1.0   0.0    1        DATA  113
CBAR      590504    202  590045  590500   0.0   1.0   0.0    1        DATA  114
CBAR      590505    202  590060  590500   0.0   1.0   0.0    1        DATA  115
CBAR      590506    202  590075  590500   0.0   1.0   0.0    1        DATA  116
CBAR      590507    202  590090  590500   0.0   1.0   0.0    1        DATA  117
CBAR      590508    202  590105  590500   0.0   1.0   0.0    1        DATA  118
CBAR      590509    202  590120  590500   0.0   1.0   0.0    1        DATA  119
CBAR      590510    202  590135  590500   0.0   1.0   0.0    1        DATA  120
CBAR      590511    202  590150  590500   0.0   1.0   0.0    1        DATA  121
CBAR      590512    202  590165  590500   0.0   1.0   0.0    1        DATA  122
CBAR      590513    201  590180  590500   0.0   1.0   0.0    1        DATA  123
$                                                                     DATA  124
$      ELEMENT CONGRUENCY...(ELBCW)        THETA DIRECTION ONLY       DATA  125
$                           (STRAIGHT SEC) BOTH DIRECTIONS            DATA  126
$                                                                     DATA  127
CNGRNT    390000  390015                                              DATA  128
CNGRNT    390000  390030                                              DATA  129
CNGRNT    390000  390045                                              DATA  130
CNGRNT    390000  390060                                              DATA  131
CNGRNT    390000  390075                                              DATA  132
CNGRNT    390000  390090                                              DATA  133
CNGRNT    390000  390105                                              DATA  134
CNGRNT    390000  390120                                              DATA  135
CNGRNT    390000  390135                                              DATA  136
CNGRNT    390000  390150                                              DATA  137
CNGRNT    390000  390165                                              DATA  138
CNGRNT    400000  400015                                              DATA  139
CNGRNT    400000  400030                                              DATA  140
CNGRNT    400000  400045                                              DATA  141
CNGRNT    400000  400060                                              DATA  142
CNGRNT    400000  400075                                              DATA  143
CNGRNT    400000  400090                                              DATA  144
CNGRNT    400000  400105                                              DATA  145
CNGRNT    400000  400120                                              DATA  146
CNGRNT    400000  400135                                              DATA  147
CNGRNT    400000  400150                                              DATA  148
CNGRNT    400000  400165                                              DATA  149
CNGRNT    400000  410000                                              DATA  150
CNGRNT    400000  410015                                              DATA  151
CNGRNT    400000  410030                                              DATA  152
CNGRNT    400000  410045                                              DATA  153
CNGRNT    400000  410060                                              DATA  154
CNGRNT    400000  410075                                              DATA  155
CNGRNT    400000  410090                                              DATA  156
CNGRNT    400000  410105                                              DATA  157
CNGRNT    400000  410120                                              DATA  158
CNGRNT    400000  410135                                              DATA  159
CNGRNT    400000  410150                                              DATA  160
CNGRNT    400000  410165                                              DATA  161
CNGRNT    400000  420000                                              DATA  162
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CNGRNT   400000  420015                                   DATA  163
CNGRNT   400000  420030                                   DATA  164
CNGRNT   400000  420045                                   DATA  165
CNGRNT   400000  420060                                   DATA  166
CNGRNT   400000  420075                                   DATA  167
CNGRNT   400000  420090                                   DATA  168
CNGRNT   400000  420105                                   DATA  169
CNGRNT   400000  420120                                   DATA  170
CNGRNT   400000  420135                                   DATA  171
CNGRNT   400000  420150                                   DATA  172
CNGRNT   400000  420165                                   DATA  173
CNGRNT   400000  430000                                   DATA  174
CNGRNT   400000  430015                                   DATA  175
CNGRNT   400000  430030                                   DATA  176
CNGRNT   400000  430045                                   DATA  177
CNGRNT   400000  430060                                   DATA  178
CNGRNT   400000  430075                                   DATA  179
CNGRNT   400000  430090                                   DATA  180
CNGRNT   400000  430105                                   DATA  181
CNGRNT   400000  430120                                   DATA  182
CNGRNT   400000  430135                                   DATA  183
CNGRNT   400000  430150                                   DATA  184
CNGRNT   400000  430165                                   DATA  185
CNGRNT   400000  440000                                   DATA  186
CNGRNT   400000  440015                                   DATA  187
CNGRNT   400000  440030                                   DATA  188
CNGRNT   400000  440045                                   DATA  189
CNGRNT   400000  440060                                   DATA  190
CNGRNT   400000  440075                                   DATA  191
CNGRNT   400000  440090                                   DATA  192
CNGRNT   400000  440105                                   DATA  193
CNGRNT   400000  440120                                   DATA  194
CNGRNT   400000  440135                                   DATA  195
CNGRNT   400000  440150                                   DATA  196
CNGRNT   400000  440165                                   DATA  197
CNGRNT   400000  450000                                   DATA  198
CNGRNT   400000  450015                                   DATA  199
CNGRNT   400000  450030                                   DATA  200
CNGRNT   400000  450045                                   DATA  201
CNGRNT   400000  450060                                   DATA  202
CNGRNT   400000  450075                                   DATA  203
CNGRNT   400000  450090                                   DATA  204
CNGRNT   400000  450105                                   DATA  205
CNGRNT   400000  450120                                   DATA  206
CNGRNT   400000  450135                                   DATA  207
CNGRNT   400000  450150                                   DATA  208
CNGRNT   400000  450165                                   DATA  209
CNGRNT   400000  460000                                   DATA  210
CNGRNT   400000  460015                                   DATA  211
CNGRNT   400000  460030                                   DATA  212
CNGRNT   400000  460045                                   DATA  213
CNGRNT   400000  460060                                   DATA  214
CNGRNT   400000  460075                                   DATA  215
CNGRNT   400000  460090                                   DATA  216
```

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CNGRNT   400000   460105          DATA   217
CNGRNT   400000   460120          DATA   218
CNGRNT   400000   460135          DATA   219
CNGRNT   400000   460150          DATA   220
CNGRNT   400000   460165          DATA   221
CNGRNT   400000   470000          DATA   222
CNGRNT   400000   470015          DATA   223
CNGRNT   400000   470030          DATA   224
CNGRNT   400000   470045          DATA   225
CNGRNT   400000   470060          DATA   226
CNGRNT   400000   470075          DATA   227
CNGRNT   400000   470090          DATA   228
CNGRNT   400000   470105          DATA   229
CNGRNT   400000   470120          DATA   230
CNGRNT   400000   470135          DATA   231
CNGRNT   400000   470150          DATA   232
CNGRNT   400000   470165          DATA   233
CNGRNT   480000   480015          DATA   234
CNGRNT   480000   480030          DATA   235
CNGRNT   480000   480045          DATA   236
CNGRNT   480000   480060          DATA   237
CNGRNT   480000   480075          DATA   238
CNGRNT   480000   480090          DATA   239
CNGRNT   480000   480105          DATA   240
CNGRNT   480000   480120          DATA   241
CNGRNT   480000   480135          DATA   242
CNGRNT   480000   480150          DATA   243
CNGRNT   480000   480165          DATA   244
CNGRNT   503008   508008          DATA   245
CNGRNT   503008   513008          DATA   246
CNGRNT   503008   519008          DATA   247
CNGRNT   503008   524008          DATA   248
CNGRNT   503008   529008          DATA   249
CNGRNT   503008   534008          DATA   250
CNGRNT   503008   540008          DATA   251
CNGRNT   503008   545008          DATA   252
CNGRNT   503008   550008          DATA   253
CNGRNT   503008   556008          DATA   254
CNGRNT   503008   561008          DATA   255
CNGRNT   503008   566008          DATA   256
CNGRNT   503008   571008          DATA   257
CNGRNT   503008   577008          DATA   258
CNGRNT   503008   582008          DATA   259
CNGRNT   503008   587008          DATA   260
CNGRNT   503023   508023          DATA   261
CNGRNT   503023   513023          DATA   262
CNGRNT   503023   519023          DATA   263
CNGRNT   503023   524023          DATA   264
CNGRNT   503023   529023          DATA   265
CNGRNT   503023   534023          DATA   266
CNGRNT   503023   540023          DATA   267
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CNGRNT     503128  534128                    DATA   378
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CNGRNT    610000  640045                                  DATA  486
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CNGRNT  610000  680135      DATA 540
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CNGRNT    610000  690150                                                                    DATA  553
CNGRNT    610000  690165                                                                    DATA  554
$                                                                                           DATA  555
$                    ELBOW DEFINED IN COORD SYSTEM 1                                        DATA  556
$         STRAIGHT BOTTOM  DEFINED IN COORD SYSTEM 2                                        DATA  557
$         STRAIGHT TOP     DEFINED IN COORD SYSTEM 3                                        DATA  558
$         ORNL CARTESIAN SYSTEM IS NO. 4                                                    DATA  559
$                                                                                           DATA  560
CORD2C  1       0       0.      0.      0.      0.      0.      1.      +COR1               DATA  561
+COR1   1.      0.      0.                                                                  DATA  562
CORD2C  2       0       0.      15.     0.      -1.     15.     0.      +COR2               DATA  563
+COR2   0.      14.     0.                                                                  DATA  564
CORD2C  3       0       15.     0.      0.      15.     1.      0.      +COR3               DATA  565
+COR3   14.     0.      0.                                                                  DATA  566
CORD2R  4       0       0.      0.      0.      0.      0.      -1.     +COR4               DATA  567
+COR4   1.      0.      0.                                                                  DATA  568
$                                                                                           DATA  569
$       FINITE ELEMENT PLATING                                                              DATA  570
$                                                                                           DATA  571
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CQUAD2    620045    200  620045  630045  630060  620060        DATA  947
CQUAD2    620060    200  620060  630060  630075  620075        DATA  948
CQUAD2    620075    200  620075  630075  630090  620090        DATA  949
CQUAD2    620090    200  620090  630090  630105  620105        DATA  950
CQUAD2    620105    200  620105  630105  630120  620120        DATA  951
CQUAD2    620120    200  620120  630120  630135  620135        DATA  952
CQUAD2    620135    200  620135  630135  630150  620150        DATA  953
CQUAD2    620150    200  620150  630150  630165  620165        DATA  954
CQUAD2    620165    200  620165  630165  630180  620180        DATA  955
CQUAD2    630000    200  630000  640000  640015  630015        DATA  956
CQUAD2    630015    200  630015  640015  640030  630030        DATA  957
CQUAD2    630030    200  630030  640030  640045  630045        DATA  958
CQUAD2    630045    200  630045  640045  640060  630060        DATA  959
CQUAD2    630060    200  630060  640060  640075  630075        DATA  960
CQUAD2    630075    200  630075  640075  640090  630090        DATA  961
CQUAD2    630090    200  630090  640090  640105  630105        DATA  962
CQUAD2    630105    200  630105  640105  640120  630120        DATA  963
CQUAD2    630120    200  630120  640120  640135  630135        DATA  964
CQUAD2    630135    200  630135  640135  640150  630150        DATA  965
CQUAD2    630150    200  630150  640150  640165  630165        DATA  966
CQUAD2    630165    200  630165  640165  640180  630180        DATA  967
CQUAD2    640000    200  640000  650000  650015  640015        DATA  968
CQUAD2    640015    200  640015  650015  650030  640030        DATA  969
CQUAD2    640030    200  640030  650030  650045  640045        DATA  970
CQUAD2    640045    200  640045  650045  650060  640060        DATA  971
CQUAD2    640060    200  640060  650060  650075  640075        DATA  972
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CQUAD2	640090	200	640090	650090	650105	640105	DATA	974
CQUAD2	640105	200	640105	650105	650120	640120	DATA	975
CQUAD2	640120	200	640120	650120	650135	640135	DATA	976
CQUAD2	640135	200	640135	650135	650150	640150	DATA	977
CQUAD2	640150	200	640150	650150	650165	640165	DATA	978
CQUAD2	640165	200	640165	650165	650180	640180	DATA	979
CQUAD2	650000	200	650000	660000	660015	650015	DATA	980
CQUAD2	650015	200	650015	660015	660030	650030	DATA	981
CQUAD2	650030	200	650030	660030	660045	650045	DATA	982
CQUAD2	650045	200	650045	660045	660060	650060	DATA	983
CQUAD2	650060	200	650060	660060	660075	650075	DATA	984
CQUAD2	650075	200	650075	660075	660090	650090	DATA	985
CQUAD2	650090	200	650090	660090	660105	650105	DATA	986
CQUAD2	650105	200	650105	660105	660120	650120	DATA	987
CQUAD2	650120	200	650120	660120	660135	650135	DATA	988
CQUAD2	650135	200	650135	660135	660150	650150	DATA	989
CQUAD2	650150	200	650150	660150	660165	650165	DATA	990
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CQUAD2	660000	200	660000	670000	670015	660015	DATA	992
CQUAD2	660015	200	660015	670015	670030	660030	DATA	993
CQUAD2	660030	200	660030	670030	670045	660045	DATA	994
CQUAD2	660045	200	660045	670045	670060	660060	DATA	995
CQUAD2	660060	200	660060	670060	670075	660075	DATA	996
CQUAD2	660075	200	660075	670075	670090	660090	DATA	997
CQUAD2	660090	200	660090	670090	670105	660105	DATA	998
CQUAD2	660105	200	660105	670105	670120	660120	DATA	999
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CQUAD2	660135	200	660135	670135	670150	660150	DATA	1001
CQUAD2	660150	200	660150	670150	670165	660165	DATA	1002
CQUAD2	660165	200	660165	670165	670180	660180	DATA	1003
CQUAD2	670000	200	670000	680000	680015	670015	DATA	1004
CQUAD2	670015	200	670015	680015	680030	670030	DATA	1005
CQUAD2	670030	200	670030	680030	680045	670045	DATA	1006
CQUAD2	670045	200	670045	680045	680060	670060	DATA	1007
CQUAD2	670060	200	670060	680060	680075	670075	DATA	1008
CQUAD2	670075	200	670075	680075	680090	670090	DATA	1009
CQUAD2	670090	200	670090	680090	680105	670105	DATA	1010
CQUAD2	670105	200	670105	680105	680120	670120	DATA	1011
CQUAD2	670120	200	670120	680120	680135	670135	DATA	1012
CQUAD2	670135	200	670135	680135	680150	670150	DATA	1013
CQUAD2	670150	200	670150	680150	680165	670165	DATA	1014
CQUAD2	670165	200	670165	680165	680180	670180	DATA	1015
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CQUAD2	680015	200	680015	690015	690030	680030	DATA	1017
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CQUAD2	680045	200	680045	690045	690060	680060	DATA	1019
CQUAD2	680060	200	680060	690060	690075	680075	DATA	1020
CQUAD2	680075	200	680075	690075	690090	680090	DATA	1021
CQUAD2	680090	200	680090	690090	690105	680105	DATA	1022
CQUAD2	680105	200	680105	690105	690120	680120	DATA	1023
CQUAD2	680120	200	680120	690120	690135	680135	DATA	1024
CQUAD2	680135	200	680135	690135	690150	680150	DATA	1025
CQUAD2	680150	200	680150	690150	690165	680165	DATA	1026

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COQUAD2    680165      200  680165  690165  690180  680180               DATA  1027
CQUAD2     690000      200  690000  700000  700015  690015               DATA  1028
CQUAD2     690015      200  690015  700015  700030  690030               DATA  1029
CQUAD2     690030      200  690030  700030  700045  690045               DATA  1030
CQUAD2     690045      200  690045  700045  700060  690060               DATA  1031
CQUAD2     690060      200  690060  700060  700075  690075               DATA  1032
CQUAD2     690075      200  690075  700075  700090  690090               DATA  1033
CQUAD2     690090      200  690090  700090  700105  690105               DATA  1034
CQUAD2     690105      200  690105  700105  700120  690120               DATA  1035
CQUAD2     690120      200  690120  700120  700135  690135               DATA  1036
CQUAD2     690135      200  690135  700135  700150  690150               DATA  1037
CQUAD2     690150      200  690150  700150  700165  690165               DATA  1038
CQUAD2     690165      200  690165  700165  700180  690180               DATA  1039
$                                                                        DATA  1040
$        RIGID CONNECTION FOR FREE  (LOADED) END OF PIPE                 DATA  1041
$                                                                        DATA  1042
CRIGD1   1        200500  100500                                         DATA  1043
CRIGD1          2  200500  390000                                        DATA  1044
CRIGD1          3  200500  390015                                        DATA  1045
CRIGD1          4  200500  390030                                        DATA  1046
CRIGD1          5  200500  390045                                        DATA  1047
CRIGD1          6  200500  390060                                        DATA  1048
CRIGD1          7  200500  390075                                        DATA  1049
CRIGD1          8  200500  390090                                        DATA  1050
CRIGD1          9  200500  390105                                        DATA  1051
CRIGD1         10  200500  390120                                        DATA  1052
CRIGD1         11  200500  390135                                        DATA  1053
CRIGD1         12  200500  390150                                        DATA  1054
CRIGD1         13  200500  390165                                        DATA  1055
CRIGD1         14  200500  390180                                        DATA  1056
$                                                                        DATA  1057
$        END CAP LOAD DUE TO UNIT INTERNAL PRESSURE                      DATA  1058
$                                                                        DATA  1059
FORCE          21  200500       3 41.3954      0.       0.     -1.       DATA  1060
$                                                                        DATA  1061
$        GRID POINTS                                                     DATA  1062
$                                                                        DATA  1063
$        MYTHICAL CENTER POINT 1 UNIT BEYOND FREE END OF PIPE            DATA  1064
$                                                                        DATA  1065
GRID     100500  0        15.0    -22.0    0.      4                     DATA  1066
$                                                                        DATA  1067
$        MYTHICAL CENTER POINT AT FREE END OF PIPE                       DATA  1068
$                                                                        DATA  1069
GRID     200500  0        15.0    -21.0    0.      4                     DATA  1070
$                                                                        DATA  1071
$        STRAIGHT SECTION ABOVE THETA=0                                  DATA  1072
$                                                                        DATA  1073
GRID       390000        3  5.1630   0.000-21.0000        3              DATA  1074
GRID       390015        3  5.1630  15.000-21.0000        3              DATA  1075
GRID       390030        3  5.1630  30.000-21.0000        3              DATA  1076
GRID       390045        3  5.1630  45.000-21.0000        3              DATA  1077
GRID       390060        3  5.1630  60.000-21.0000        3              DATA  1078
GRID       390075        3  5.1630  75.000-21.0000        3              DATA  1079
GRID       390090        3  5.1630  90.000-21.0000        3              DATA  1080
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GRID      390105      3  5.1630 105.000-21.0000       3                         DATA  1081
GRID      390120      3  5.1630 120.000-21.0000       3                         DATA  1082
GRID      390135      3  5.1630 135.000-21.0000       3                         DATA  1083
GRID      390150      3  5.1630 150.000-21.0000       3                         DATA  1084
GRID      390165      3  5.1630 165.000-21.0000       3                         DATA  1085
GRID      390180      3  5.1630 180.000-21.0000       3                         DATA  1086
GRID      400000      3  5.1630   0.000-18.5000       3                         DATA  1087
GRID      400015      3  5.1630  15.000-18.5000       3                         DATA  1088
GRID      400030      3  5.1630  30.000-18.5000       3                         DATA  1089
GRID      400045      3  5.1630  45.000-18.5000       3                         DATA  1090
GRID      400060      3  5.1630  60.000-18.5000       3                         DATA  1091
GRID      400075      3  5.1630  75.000-18.5000       3                         DATA  1092
GRID      400090      3  5.1630  90.000-18.5000       3                         DATA  1093
GRID      400105      3  5.1630 105.000-18.5000       3                         DATA  1094
GRID      400120      3  5.1630 120.000-18.5000       3                         DATA  1095
GRID      400135      3  5.1630 135.000-18.5000       3                         DATA  1096
GRID      400150      3  5.1630 150.000-18.5000       3                         DATA  1097
GRID      400165      3  5.1630 165.000-18.5000       3                         DATA  1098
GRID      400180      3  5.1630 180.000-18.5000       3                         DATA  1099
GRID      410000      3  5.1630   0.000-16.5000       3                         DATA  1100
GRID      410015      3  5.1630  15.000-16.5000       3                         DATA  1101
GRID      410030      3  5.1630  30.000-16.5000       3                         DATA  1102
GRID      410045      3  5.1630  45.000-16.5000       3                         DATA  1103
GRID      410060      3  5.1630  60.000-16.5000       3                         DATA  1104
GRID      410075      3  5.1630  75.000-16.5000       3                         DATA  1105
GRID      410090      3  5.1630  90.000-16.5000       3                         DATA  1106
GRID      410105      3  5.1630 105.000-16.5000       3                         DATA  1107
GRID      410120      3  5.1630 120.000-16.5000       3                         DATA  1108
GRID      410135      3  5.1630 135.000-16.5000       3                         DATA  1109
GRID      410150      3  5.1630 150.000-16.5000       3                         DATA  1110
GRID      410165      3  5.1630 165.000-16.5000       3                         DATA  1111
GRID      410180      3  5.1630 180.000-16.5000       3                         DATA  1112
GRID      420000      3  5.1630   0.000-14.5000       3                         DATA  1113
GRID      420015      3  5.1630  15.000-14.5000       3                         DATA  1114
GRID      420030      3  5.1630  30.000-14.5000       3                         DATA  1115
GRID      420045      3  5.1630  45.000-14.5000       3                         DATA  1116
GRID      420060      3  5.1630  60.000-14.5000       3                         DATA  1117
GRID      420075      3  5.1630  75.000-14.5000       3                         DATA  1118
GRID      420090      3  5.1630  90.000-14.5000       3                         DATA  1119
GRID      420105      3  5.1630 105.000-14.5000       3                         DATA  1120
GRID      420120      3  5.1630 120.000-14.5000       3                         DATA  1121
GRID      420135      3  5.1630 135.000-14.5000       3                         DATA  1122
GRID      420150      3  5.1630 150.000-14.5000       3                         DATA  1123
GRID      420165      3  5.1630 165.000-14.5000       3                         DATA  1124
GRID      420180      3  5.1630 180.000-14.5000       3                         DATA  1125
GRID      430000      3  5.1630   0.000-12.5000       3                         DATA  1126
GRID      430015      3  5.1630  15.000-12.5000       3                         DATA  1127
GRID      430030      3  5.1630  30.000-12.5000       3                         DATA  1128
GRID      430045      3  5.1630  45.000-12.5000       3                         DATA  1129
GRID      430060      3  5.1630  60.000-12.5000       3                         DATA  1130
GRID      430075      3  5.1630  75.000-12.5000       3                         DATA  1131
GRID      430090      3  5.1630  90.000-12.5000       3                         DATA  1132
GRID      430105      3  5.1630 105.000-12.5000       3                         DATA  1133
GRID      430120      3  5.1630 120.000-12.5000       3                         DATA  1134
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GRID     430135     3  5.1630  135.000-12.5000     3            DATA  1135
GRID     430150     3  5.1630  150.000-12.5000     3            DATA  1136
GRID     430165     3  5.1630  165.000-12.5000     3            DATA  1137
GRID     430180     3  5.1630  180.000-12.5000     3            DATA  1138
GRID     440000     3  5.1630    0.000-10.5000     3            DATA  1139
CRID     440015     3  5.1630   15.000-10.5000     3            DATA  1140
GRID     440030     3  5.1630   30.000-10.5000     3            DATA  1141
GRID     440045     3  5.1630   45.000-10.5000     3            DATA  1142
GRID     440060     3  5.1630   60.000-10.5000     3            DATA  1143
GRID     440075     3  5.1630   75.000-10.5000     3            DATA  1144
GRID     440090     3  5.1630   90.000-10.5000     3            DATA  1145
GRID     440105     3  5.1630  105.000-10.5000     3            DATA  1146
GRID     440120     3  5.1630  120.000-10.5000     3            DATA  1147
GRID     440135     3  5.1630  135.000-10.5000     3            DATA  1148
GRID     440150     3  5.1630  150.000-10.5000     3            DATA  1149
GRID     440165     3  5.1630  165.000-10.5000     3            DATA  1150
GRID     440180     3  5.1630  180.000-10.5000     3            DATA  1151
GRID     450000     3  5.1630    0.000 -8.5000     3            DATA  1152
GRID     450015     3  5.1630   15.000 -8.5000     3            DATA  1153
GRID     450030     3  5.1630   30.000 -8.5000     3            DATA  1154
GRID     450045     3  5.1630   45.000 -8.5000     3            DATA  1155
GRID     450060     3  5.1630   60.000 -8.5000     3            DATA  1156
GRID     450075     3  5.1630   75.000 -8.5000     3            DATA  1157
GRID     450090     3  5.1630   90.000 -8.5000     3            DATA  1158
GRID     450105     3  5.1630  105.000 -8.5000     3            DATA  1159
GRID     450120     3  5.1630  120.000 -8.5000     3            DATA  1160
GRID     450135     3  5.1630  135.000 -8.5000     3            DATA  1161
GRID     450150     3  5.1630  150.000 -8.5000     3            DATA  1162
GRID     450165     3  5.1630  165.000 -8.5000     3            DATA  1163
GRID     450180     3  5.1630  180.000 -8.5000     3            DATA  1164
GRID     460000     3  5.1630    0.000 -6.5000     3            DATA  1165
GRID     460015     3  5.1630   15.000 -6.5000     3            DATA  1166
GRID     460030     3  5.1630   30.000 -6.5000     3            DATA  1167
GRID     460045     3  5.1630   45.000 -6.5000     3            DATA  1168
GRID     460060     3  5.1630   60.000 -6.5000     3            DATA  1169
GRID     460075     3  5.1630   75.000 -6.5000     3            DATA  1170
GRID     460090     3  5.1630   90.000 -6.5000     3            DATA  1171
GRID     460105     3  5.1630  105.000 -6.5000     3            DATA  1172
GRID     460120     3  5.1630  120.000 -6.5000     3            DATA  1173
GRID     460135     3  5.1630  135.000 -6.5000     3            DATA  1174
GRID     460150     3  5.1630  150.000 -6.5000     3            DATA  1175
GRID     460165     3  5.1630  165.000 -6.5000     3            DATA  1176
GRID     460180     3  5.1630  180.000 -6.5000     3            DATA  1177
GRID     470000     3  5.1630    0.000 -4.5000     3            DATA  1178
GRID     470015     3  5.1630   15.000 -4.5000     3            DATA  1179
GRID     470030     3  5.1630   30.000 -4.5000     3            DATA  1180
GRID     470045     3  5.1630   45.000 -4.5000     3            DATA  1181
GRID     470060     3  5.1630   60.000 -4.5000     3            DATA  1182
GRID     470075     3  5.1630   75.000 -4.5000     3            DATA  1183
GRID     470090     3  5.1630   90.000 -4.5000     3            DATA  1184
GRID     470105     3  5.1630  105.000 -4.5000     3            DATA  1185
GRID     470120     3  5.1630  120.000 -4.5000     3            DATA  1186
GRID     470135     3  5.1630  135.000 -4.5000     3            DATA  1187
GRID     470150     3  5.1630  150.000 -4.5000     3            DATA  1188
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GRID      470165     3  5.1630 165.000 -4.5000       3                  DATA  1189
GRID      470180     3  5.1630 180.000 -4.5000       3                  DATA  1190
GRID      480000     3  5.1630   0.000 -2.5000       3                  DATA  1191
GRID      480015     3  5.1630  15.000 -2.5000       3                  DATA  1192
GRID      480030     3  5.1630  30.000 -2.5000       3                  DATA  1193
GRID      480045     3  5.1630  45.000 -2.5000       3                  DATA  1194
GRID      480060     3  5.1630  60.000 -2.5000       3                  DATA  1195
GRID      480075     3  5.1630  75.000 -2.5000       3                  DATA  1196
GRID      480090     3  5.1630  90.000 -2.5000       3                  DATA  1197
GRID      480105     3  5.1630 105.000 -2.5000       3                  DATA  1198
GRID      480120     3  5.1630 120.000 -2.5000       3                  DATA  1199
GRID      480135     3  5.1630 135.000 -2.5000       3                  DATA  1200
GRID      480150     3  5.1630 150.000 -2.5000       3                  DATA  1201
GRID      480165     3  5.1630 165.000 -2.5000       3                  DATA  1202
GRID      480180     3  5.1630 130.000 -2.5000       3                  DATA  1203
GRID      490000     3  5.1630   0.000 -1.0000       3                  DATA  1204
GRID      490015     3  5.1630  15.000 -1.0000       3                  DATA  1205
GRID      490030     3  5.1630  30.000 -1.0000       3                  DATA  1206
GRID      490045     3  5.1630  45.000 -1.0000       3                  DATA  1207
GRID      490060     3  5.1630  60.000 -1.0000       3                  DATA  1208
GRID      490075     3  5.1630  75.000 -1.0000       3                  DATA  1209
GRID      490090     3  5.1630  90.000 -1.0000       3                  DATA  1210
GRID      490105     3  5.1630 105.000 -1.0000       3                  DATA  1211
GRID      490120     3  5.1630 120.000 -1.0000       3                  DATA  1212
GRID      490135     3  5.1630 135.000 -1.0000       3                  DATA  1213
GRID      490150     3  5.1630 150.000 -1.0000       3                  DATA  1214
GRID      490165     3  5.1630 165.000 -1.0000       3                  DATA  1215
GRID      490180     3  5.1630 180.000 -1.0000       3                  DATA  1216
$                                                                       DATA  1217
$        MYTHICAL CENTER POINT AT THETA=0 END OF ELBOW                  DATA  1218
$              (EQUIV TO ORIGIN OF COORD SYS 3)                         DATA  1219
$                                                                       DATA  1220
GRID     500500  0       15.0    0.      0.      4                      DATA  1221
$                                                                       DATA  1222
$        ELBOW POINTS                                                   DATA  1223
$                                                                       DATA  1224
GRID      500000     1  9.8370   0.000  0.0000       1                  DATA  1225
GRID      500015     1 10.0129   0.000  1.3363       1                  DATA  1226
GRID      500030     1 10.5287   0.000  2.5815       1                  DATA  1227
GRID      500045     1 11.3492   0.000  3.6508       1                  DATA  1228
GRID      500060     1 12.4185   0.000  4.4713       1                  DATA  1229
GRID      500075     1 13.6637   0.000  4.9871       1                  DATA  1230
GRID      500090     1 15.0000   0.000  5.1630       1                  DATA  1231
GRID      500105     1 16.3363   0.000  4.9871       1                  DATA  1232
GRID      500120     1 17.5815   0.000  4.4713       1                  DATA  1233
GRID      500135     1 18.6508   0.000  3.6508       1                  DATA  1234
GRID      500150     1 19.4713   0.000  2.5815       1                  DATA  1235
GRID      500165     1 19.9871   0.000  1.3363       1                  DATA  1236
GRID      500180     1 20.1630   0.000  -.0000       1                  DATA  1237
GRID      505000     1  9.8370   5.294  0.0000       1                  DATA  1238
GRID      505015     1 10.0129   5.294  1.3363       1                  DATA  1239
GRID      505030     1 10.5287   5.294  2.5815       1                  DATA  1240
GRID      505045     1 11.3492   5.294  3.6508       1                  DATA  1241
GRID      505060     1 12.4185   5.294  4.4713       1                  DATA  1242
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GRID	505075	1	13.6637	5.294	4.9871	1	DATA	1243
GRID	505090	1	15.0000	5.294	5.1630	1	DATA	1244
GRID	505105	1	16.3363	5.294	4.9871	1	DATA	1245
GRID	505120	1	17.5815	5.294	4.4713	1	DATA	1246
GRID	505135	1	18.6508	5.294	3.6508	1	DATA	1247
GRID	505150	1	19.4713	5.294	2.5815	1	DATA	1248
GRID	505165	1	19.9871	5.294	1.3363	1	DATA	1249
GRID	505180	1	20.1630	5.294	-.0000	1	DATA	1250
GRID	511000	1	9.8370	10.588	0.0000	1	DATA	1251
GRID	511015	1	10.0129	10.588	1.3363	1	DATA	1252
GRID	511030	1	10.5287	10.588	2.5815	1	DATA	1253
GRID	511045	1	11.3492	10.588	3.6508	1	DATA	1254
GRID	511060	1	12.4185	10.588	4.4713	1	DATA	1255
GRID	511075	1	13.6637	10.588	4.9871	1	DATA	1256
GRID	511090	1	15.0000	10.588	5.1630	1	DATA	1257
GRID	511105	1	16.3363	10.588	4.9871	1	DATA	1258
GRID	511120	1	17.5815	10.588	4.4713	1	DATA	1259
GRID	511135	1	18.6508	10.588	3.6508	1	DATA	1260
GRID	511150	1	19.4713	10.588	2.5815	1	DATA	1261
GRID	511165	1	19.9871	10.588	1.3363	1	DATA	1262
GRID	511180	1	20.1630	10.588	-.0000	1	DATA	1263
GRID	516000	1	9.8370	15.882	0.0000	1	DATA	1264
GRID	516015	1	10.0129	15.882	1.3363	1	DATA	1265
GRID	516030	1	10.5287	15.882	2.5815	1	DATA	1266
GRID	516045	1	11.3492	15.882	3.6508	1	DATA	1267
GRID	516060	1	12.4185	15.882	4.4713	1	DATA	1268
GRID	516075	1	13.6637	15.882	4.9871	1	DATA	1269
GRID	516090	1	15.0000	15.882	5.1630	1	DATA	1270
GRID	516105	1	16.3363	15.882	4.9871	1	DATA	1271
GRID	516120	1	17.5815	15.882	4.4713	1	DATA	1272
GRID	516135	1	18.6508	15.882	3.6508	1	DATA	1273
GRID	516150	1	19.4713	15.882	2.5815	1	DATA	1274
GRID	516165	1	19.9871	15.882	1.3363	1	DATA	1275
GRID	516180	1	20.1630	15.882	-.0000	1	DATA	1276
GRID	521000	1	9.8370	21.176	0.0000	1	DATA	1277
GRID	521015	1	10.0129	21.176	1.3363	1	DATA	1278
GRID	521030	1	10.5287	21.176	2.5815	1	DATA	1279
GRID	521045	1	11.3492	21.176	3.6508	1	DATA	1280
GRID	521060	1	12.4185	21.176	4.4713	1	DATA	1281
GRID	521075	1	13.6637	21.176	4.9871	1	DATA	1282
GRID	521090	1	15.0000	21.176	5.1630	1	DATA	1283
GRID	521105	1	16.3363	21.176	4.9871	1	DATA	1284
GRID	521120	1	17.5815	21.176	4.4713	1	DATA	1285
GRID	521135	1	18.6508	21.176	3.6508	1	DATA	1286
GRID	521150	1	19.4713	21.176	2.5815	1	DATA	1287
GRID	521165	1	19.9871	21.176	1.3363	1	DATA	1288
GRID	521180	1	20.1630	21.176	-.0000	1	DATA	1289
GRID	526000	1	9.8370	26.471	0.0000	1	DATA	1290
GRID	526015	1	10.0129	26.471	1.3363	1	DATA	1291
GRID	526030	1	10.5287	26.471	2.5815	1	DATA	1292
GRID	526045	1	11.3492	26.471	3.6508	1	DATA	1293
GRID	526060	1	12.4185	26.471	4.4713	1	DATA	1294
GRID	526075	1	13.6637	26.471	4.9871	1	DATA	1295
GRID	526090	1	15.0000	26.471	5.1630	1	DATA	1296

GRID	526105	1	16.3363	26.471	4.9871	1	DATA	1297
GRID	526120	1	17.5815	26.471	4.4713	1	DATA	1298
GRID	526135	1	18.6508	26.471	3.6508	1	DATA	1299
GRID	526150	1	19.4713	26.471	2.5815	1	DATA	1300
GRID	526165	1	19.9871	26.471	1.3363	1	DATA	1301
GRID	526180	1	20.1630	26.471	-.0000	1	DATA	1302
GRID	532000	1	9.8370	31.765	0.0000	1	DATA	1303
GRID	532015	1	10.0129	31.765	1.3363	1	DATA	1304
GRID	532030	1	10.5287	31.765	2.5815	1	DATA	1305
GRID	532045	1	11.3492	31.765	3.6508	1	DATA	1306
GRID	532060	1	12.4185	31.765	4.4713	1	DATA	1307
GRID	532075	1	13.6637	31.765	4.9871	1	DATA	1308
GRID	532090	1	15.0000	31.765	5.1630	1	DATA	1309
GRID	532105	1	16.3363	31.765	4.9871	1	DATA	1310
GRID	532120	1	17.5815	31.765	4.4713	1	DATA	1311
GRID	532135	1	18.6508	31.765	3.6508	1	DATA	1312
GRID	532150	1	19.4713	31.765	2.5815	1	DATA	1313
GRID	532165	1	19.9871	31.765	1.3363	1	DATA	1314
GRID	532180	1	20.1630	31.765	-.0000	1	DATA	1315
GRID	537000	1	9.8370	37.059	0.0000	1	DATA	1316
GRID	537015	1	10.0129	37.059	1.3363	1	DATA	1317
GRID	537030	1	10.5287	37.059	2.5815	1	DATA	1318
GRID	537045	1	11.3492	37.059	3.6508	1	DATA	1319
GRID	537060	1	12.4185	37.059	4.4713	1	DATA	1320
GRID	537075	1	13.6637	37.059	4.9871	1	DATA	1321
GRID	537090	1	15.0000	37.059	5.1630	1	DATA	1322
GRID	537105	1	16.3363	37.059	4.9871	1	DATA	1323
GRID	537120	1	17.5815	37.059	4.4713	1	DATA	1324
GRID	537135	1	18.6508	37.059	3.6508	1	DATA	1325
GRID	537150	1	19.4713	37.059	2.5815	1	DATA	1326
GRID	537165	1	19.9871	37.059	1.3363	1	DATA	1327
GRID	537180	1	20.1630	37.059	-.0000	1	DATA	1328
GRID	542000	1	9.8370	42.353	0.0000	1	DATA	1329
GRID	542015	1	10.0129	42.353	1.3363	1	DATA	1330
GRID	542030	1	10.5287	42.353	2.5815	1	DATA	1331
GRID	542045	1	11.3492	42.353	3.6508	1	DATA	1332
GRID	542060	1	12.4185	42.353	4.4713	1	DATA	1333
GRID	542075	1	13.6637	42.353	4.9871	1	DATA	1334
GRID	542090	1	15.0000	42.353	5.1630	1	DATA	1335
GRID	542105	1	16.3363	42.353	4.9871	1	DATA	1336
GRID	542120	1	17.5815	42.353	4.4713	1	DATA	1337
GRID	542135	1	18.6508	42.353	3.6508	1	DATA	1338
GRID	542150	1	19.4713	42.353	2.5815	1	DATA	1339
GRID	542165	1	19.9871	42.353	1.3363	1	DATA	1340
GRID	542180	1	20.1630	42.353	-.0000	1	DATA	1341
GRID	548000	1	9.8370	47.647	0.0000	1	DATA	1342
GRID	548015	1	10.0129	47.647	1.3363	1	DATA	1343
GRID	548030	1	10.5287	47.647	2.5815	1	DATA	1344
GRID	548045	1	11.3492	47.647	3.6508	1	DATA	1345
GRID	548060	1	12.4185	47.647	4.4713	1	DATA	1346
GRID	548075	1	13.6637	47.647	4.9871	1	DATA	1347
GRID	548090	1	15.0000	47.647	5.1630	1	DATA	1348
GRID	548105	1	16.3363	47.647	4.9871	1	DATA	1349
GRID	548120	1	17.5815	47.647	4.4713	1	DATA	1350

GRID	548135	1	18.6508	47.647	3.6508	1	DATA	1351
GRID	548150	1	19.4713	47.647	2.5815	1	DATA	1352
GRID	548165	1	19.9871	47.647	1.3363	1	DATA	1353
GRID	548180	1	20.1630	47.647	-.0000	1	DATA	1354
GRID	553000	1	9.8370	52.941	0.0000	1	DATA	1355
GRID	553015	1	10.0129	52.941	1.3363	1	DATA	1356
GRID	553030	1	10.5287	52.941	2.5815	1	DATA	1357
GRID	553045	1	11.3492	52.941	3.6508	1	DATA	1358
GRID	553060	1	12.4185	52.941	4.4713	1	DATA	1359
GRID	553075	1	13.6637	52.941	4.9871	1	DATA	1360
GRID	553090	1	15.0000	52.941	5.1630	1	DATA	1361
GRID	553105	1	16.3363	52.941	4.9871	1	DATA	1362
GRID	553120	1	17.5815	52.941	4.4713	1	DATA	1363
GRID	553135	1	18.6508	52.941	3.6508	1	DATA	1364
GRID	553150	1	19.4713	52.941	2.5815	1	DATA	1365
GRID	553165	1	19.9871	52.941	1.3363	1	DATA	1366
GRID	553180	1	20.1630	52.941	-.0000	1	DATA	1367
GRID	558000	1	9.8370	58.235	0.0000	1	DATA	1368
GRID	558015	1	10.0129	58.235	1.3363	1	DATA	1369
GRID	558030	1	10.5287	58.235	2.5815	1	DATA	1370
GRID	558045	1	11.3492	58.235	3.6508	1	DATA	1371
GRID	558060	1	12.4185	58.235	4.4713	1	DATA	1372
GRID	558075	1	13.6637	58.235	4.9871	1	DATA	1373
GRID	558090	1	15.0000	58.235	5.1630	1	DATA	1374
GRID	558105	1	16.3363	58.235	4.9871	1	DATA	1375
GRID	558120	1	17.5815	58.235	4.4713	1	DATA	1376
GRID	558135	1	18.6508	58.235	3.6508	1	DATA	1377
GRID	558150	1	19.4713	58.235	2.5815	1	DATA	1378
GRID	558165	1	19.9871	58.235	1.3363	1	DATA	1379
GRID	558180	1	20.1630	58.235	-.0000	1	DATA	1380
GRID	564000	1	9.8370	63.529	0.0000	1	DATA	1381
GRID	564015	1	10.0129	63.529	1.3363	1	DATA	1382
GRID	564030	1	10.5287	63.529	2.5815	1	DATA	1383
GRID	564045	1	11.3492	63.529	3.6508	1	DATA	1384
GRID	564060	1	12.4185	63.529	4.4713	1	DATA	1385
GRID	564075	1	13.6637	63.529	4.9871	1	DATA	1386
GRID	564090	1	15.0000	63.529	5.1630	1	DATA	1387
GRID	564105	1	16.3363	63.529	4.9871	1	DATA	1388
GRID	564120	1	17.5815	63.529	4.4713	1	DATA	1389
GRID	564135	1	18.6508	63.529	3.6508	1	DATA	1390
GRID	564150	1	19.4713	63.529	2.5815	1	DATA	1391
GRID	564165	1	19.9871	63.529	1.3363	1	DATA	1392
GRID	564180	1	20.1630	63.529	-.0000	1	DATA	1393
GRID	569000	1	9.8370	68.824	0.0000	1	DATA	1394
GRID	569015	1	10.0129	68.824	1.3363	1	DATA	1395
GRID	569030	1	10.5287	68.824	2.5815	1	DATA	1396
GRID	569045	1	11.3492	68.824	3.6508	1	DATA	1397
GRID	569060	1	12.4185	68.824	4.4713	1	DATA	1398
GRID	569075	1	13.6637	68.824	4.9871	1	DATA	1399
GRID	569090	1	15.0000	68.824	5.1630	1	DATA	1400
GRID	569105	1	16.3363	68.824	4.9871	1	DATA	1401
GRID	569120	1	17.5815	68.824	4.4713	1	DATA	1402
GRID	569135	1	18.6508	68.824	3.6508	1	DATA	1403
GRID	569150	1	19.4713	68.824	2.5615	1	DATA	1404

GRID	569165	1	19.9871	68.824	1.3363	1	DATA	1405
GRID	569180	1	20.1630	68.824	-.0000	1	DATA	1406
GRID	574000	1	9.8370	74.118	0.0000	1	DATA	1407
GRID	574015	1	10.0129	74.118	1.3363	1	DATA	1408
GRID	574030	1	10.5287	74.118	2.5815	1	DATA	1409
GRID	574045	1	11.3492	74.118	3.6508	1	DATA	1410
GRID	574060	1	12.4185	74.118	4.4713	1	DATA	1411
GRID	574075	1	13.6637	74.118	4.9871	1	DATA	1412
GRID	574090	1	15.0000	74.118	5.1630	1	DATA	1413
GRID	574105	1	16.3363	74.118	4.9871	1	DATA	1414
GRID	574120	1	17.5815	74.118	4.4713	1	DATA	1415
GRID	574135	1	18.6508	74.118	3.6508	1	DATA	1416
GRID	574150	1	19.4713	74.118	2.5615	1	DATA	1417
GRID	574165	1	19.9871	74.118	1.3363	1	DATA	1418
GRID	574180	1	20.1630	74.118	-.0000	1	DATA	1419
GRID	579000	1	9.8370	79.412	0.0000	1	DATA	1420
GRID	579015	1	10.0129	79.412	1.3363	1	DATA	1421
GRID	579030	1	10.5287	79.412	2.5815	1	DATA	1422
GRID	579045	1	11.3492	79.412	3.6508	1	DATA	1423
GRID	579060	1	12.4185	79.412	4.4713	1	DATA	1424
GRID	579075	1	13.6637	79.412	4.9871	1	DATA	1425
GRID	579090	1	15.0000	79.412	5.1630	1	DATA	1426
GRID	579105	1	16.3363	79.412	4.9871	1	DATA	1427
GRID	579120	1	17.5815	79.412	4.4713	1	DATA	1428
GRID	579135	1	18.6508	79.412	3.6508	1	DATA	1429
GRID	579150	1	19.4713	79.412	2.5815	1	DATA	1430
GRID	579165	1	19.9871	79.412	1.3363	1	DATA	1431
GRID	579180	1	20.1630	79.412	-.0000	1	DATA	1432
GRID	585000	1	9.8370	84.706	0.0000	1	DATA	1433
GRID	585015	1	10.0129	84.706	1.3363	1	DATA	1434
GRID	585030	1	10.5287	84.706	2.5815	1	DATA	1435
GRID	585045	1	11.3492	84.706	3.6508	1	DATA	1436
GRID	585060	1	12.4185	84.706	4.4713	1	DATA	1437
GRID	585075	1	13.6637	84.706	4.9871	1	DATA	1438
GRID	585090	1	15.0000	84.706	5.1630	1	DATA	1439
GRID	585105	1	16.3363	84.706	4.9871	1	DATA	1440
GRID	585120	1	17.5815	84.706	4.4713	1	DATA	1441
GRID	585135	1	18.6508	84.706	3.6508	1	DATA	1442
GRID	585150	1	19.4713	84.706	2.5815	1	DATA	1443
GRID	585165	1	19.9871	84.706	1.3363	1	DATA	1444
GRID	585180	1	20.1630	84.706	-.0000	1	DATA	1445
GRID	590000	1	9.8370	90.000	0.0000	1	DATA	1446
GRID	590015	1	10.0129	90.000	1.3363	1	DATA	1447
GRID	590030	1	10.5287	90.000	2.5815	1	DATA	1448
GRID	590045	1	11.3492	90.000	3.6508	1	DATA	1449
GRID	590060	1	12.4185	90.000	4.4713	1	DATA	1450
GRID	590075	1	13.6637	90.000	4.9871	1	DATA	1451
GRID	590090	1	15.0000	90.000	5.1630	1	DATA	1452
GRID	590105	1	16.3363	90.000	4.9871	1	DATA	1453
GRID	590120	1	17.5815	90.000	4.4713	1	DATA	1454
GRID	590135	1	18.6508	90.000	3.6508	1	DATA	1455
GRID	590150	1	19.4713	90.000	2.5815	1	DATA	1456
GRID	590165	1	19.9871	90.000	1.3363	1	DATA	1457
GRID	590180	1	20.1630	90.000	-.0000	1	DATA	1458

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$                                                                       DATA  1459
$       MYTHICAL CENTER POINT AT THETA=90 END OF ELBOW                  DATA  1460
$             (EQUIV TO ORIGIN OF COORD SYS 2)                          DATA  1461
GRID    590500  0       0.      15.     0.      4                       DATA  1462
$                                                                       DATA  1463
$       STRAIGHT SECTION BELOW THETA=90                                 DATA  1464
$                                                                       DATA  1465
GRID      600000       2 5.1630   0.000 1.0000        2                 DATA  1466
GRID      600015       2 5.1630  15.000 1.0000        2                 DATA  1467
GRID      600030       2 5.1630  30.000 1.0000        2                 DATA  1468
GRID      600045       2 5.1630  45.000 1.0000        2                 DATA  1469
GRID      600060       2 5.1630  60.000 1.0000        2                 DATA  1470
GRID      600075       2 5.1630  75.000 1.0000        2                 DATA  1471
GRID      600090       2 5.1630  90.000 1.0000        2                 DATA  1472
GRID      600105       2 5.1630 105.000 1.0000        2                 DATA  1473
GRID      600120       2 5.1630 120.000 1.0000        2                 DATA  1474
GRID      600135       2 5.1630 135.000 1.0000        2                 DATA  1475
GRID      600150       2 5.1630 150.000 1.0000        2                 DATA  1476
GRID      600165       2 5.1630 165.000 1.0000        2                 DATA  1477
GRID      600180       2 5.1630 180.000 1.0000        2                 DATA  1478
GRID      610000       2 5.1630   0.000 2.5000        2                 DATA  1479
GRID      610015       2 5.1630  15.000 2.5000        2                 DATA  1480
GRID      610030       2 5.1630  30.000 2.5000        2                 DATA  1481
GRID      610045       2 5.1630  45.000 2.5000        2                 DATA  1482
GRID      610060       2 5.1630  60.000 2.5000        2                 DATA  1483
GRID      610075       2 5.1630  75.000 2.5000        2                 DATA  1484
GRID      610090       2 5.1630  90.000 2.5000        2                 DATA  1485
GRID      610105       2 5.1630 105.000 2.5000        2                 DATA  1486
GRID      610120       2 5.1630 120.000 2.5000        2                 DATA  1487
GRID      610135       2 5.1630 135.000 2.5000        2                 DATA  1488
GRID      610150       2 5.1630 150.000 2.5000        2                 DATA  1489
GRID      610165       2 5.1630 165.000 2.5000        2                 DATA  1490
GRID      610180       2 5.1630 180.000 2.5000        2                 DATA  1491
GRID      620000       2 5.1630   0.000 4.5000        2                 DATA  1492
GRID      620015       2 5.1630  15.000 4.5000        2                 DATA  1493
GRID      620030       2 5.1630  30.000 4.5000        2                 DATA  1494
GRID      620045       2 5.1630  45.000 4.5000        2                 DATA  1495
GRID      620060       2 5.1630  60.000 4.5000        2                 DATA  1496
GRID      620075       2 5.1630  75.000 4.5000        2                 DATA  1497
GRID      620090       2 5.1630  90.000 4.5000        2                 DATA  1498
GRID      620105       2 5.1630 105.000 4.5000        2                 DATA  1499
GRID      620120       2 5.1630 120.000 4.5000        2                 DATA  1500
GRID      620135       2 5.1630 135.000 4.5000        2                 DATA  1501
GRID      620150       2 5.1630 150.000 4.5000        2                 DATA  1502
GRID      620165       2 5.1630 165.000 4.5000        2                 DATA  1503
GRID      620180       2 5.1630 180.000 4.5000        2                 DATA  1504
GRID      630000       2 5.1630   0.000 6.5000        2                 DATA  1505
GRID      630015       2 5.1630  15.000 6.5000        2                 DATA  1506
GRID      630030       2 5.1630  30.000 6.5000        2                 DATA  1507
GRID      630045       2 5.1630  45.000 6.5000        2                 DATA  1508
GRID      630060       2 5.1630  60.000 6.5000        2                 DATA  1509
GRID      630075       2 5.1630  75.000 6.5000        2                 DATA  1510
GRID      630090       2 5.1630  90.000 6.5000        2                 DATA  1511
GRID      630105       2 5.1630 105.000 6.5000        2                 DATA  1512
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GRID    640075    2  5.1630  75.000  8.5000     2                    DATA  1523
GRID    640090    2  5.1630  90.000  8.5000     2                    DATA  1524
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GRID    640135    2  5.1630 135.000  8.5000     2                    DATA  1527
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GRID    660180    2  5.1630 180.000 12.5000     2                    DATA  1556
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GRID    670135    2  5.1630 135.000 14.5000     2                    DATA  1566
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GRID    670180      2 5.1630 180.000 14.5000      2                 DATA  1569
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GRID    700075      2 5.1630  75.000 20.5000      2                 DATA  1601
GRID    700090      2 5.1630  90.000 20.5000      2                 DATA  1602
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GRID    700150      2 5.1630 150.000 20.5000      2                 DATA  1606
GRID    700165      2 5.1630 165.000 20.5000      2                 DATA  1607
GRID    700180      2 5.1630 180.000 20.5000      2                 DATA  1608
$                                                                   DATA  1609
MAT1    45      2.9+7           0.3     7.324-4           STEEL     DATA  1610
$                                                                   DATA  1611
$       BENDING MOMENTS APPLIED AT FREE END                         DATA  1612
$                                                                   DATA  1613
MOMENT  22      200500  0       0.50    0.      0.      1.          DATA  1614
MOMENT  23      200500  0       0.50    1.      0.      0.          DATA  1615
MOMENT  24      200500  0       0.50    0.      1.      0.          DATA  1616
$                                                                   DATA  1617
PBAR    201     45      1.0-6   1.0-9   1.0-9   2.0-9               DATA  1618
PBAR    202     45      2.0-6   2.0-9   2.0-9   4.0-9               DATA  1619
$                                                                   DATA  1620
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PLOAD2          21  -1.000  561053                                    DATA  1890
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PLOAD2          21  -1.000  577143                               DATA  1932
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PLOAD2          21  -1.000  582143                               DATA  1944
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PLOAD2         21   -1.000  587173                                            DATA  1958
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PLOAD2         21   -1.000  620030                                            DATA  1997
PLOAD2         21   -1.000  620045                                            DATA  1998
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PLOAD2          21   -1.000  630120                                    DATA  2015
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PLOAD2          21   -1.000  630150                                    DATA  2017
PLOAD2          21   -1.000  630165                                    DATA  2018
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PLOAD2          21   -1.000  640030                                    DATA  2021
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PLOAD2          21   -1.000  660045                                    DATA  2046
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PLOAD2          21   -1.000  660075                                    DATA  2048
PLOAD2          21   -1.000  660090                                    DATA  2049
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PLOAD2          21   -1.000  660120                                    DATA  2051
PLOAD2          21   -1.000  660135                                    DATA  2052
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PLOAD2        21  -1.000  670030                                        DATA  2057
PLOAD2        21  -1.000  670045                                        DATA  2058
PLOAD2        21  -1.000  670060                                        DATA  2059
PLOAD2        21  -1.000  670075                                        DATA  2060
PLOAD2        21  -1.000  670090                                        DATA  2061
PLOAD2        21  -1.000  670105                                        DATA  2062
PLOAD2        21  -1.000  670120                                        DATA  2063
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PLOAD2        21  -1.000  680045                                        DATA  2070
PLOAD2        21  -1.000  680060                                        DATA  2071
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PLOAD2        21  -1.000  680090                                        DATA  2073
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PLOAD2        21  -1.000  680120                                        DATA  2075
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PLOAD2        21  -1.000  690090                                        DATA  2085
PLOAD2        21  -1.000  690105                                        DATA  2086
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$                                                                       DATA  2093
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$                                                                       DATA  2095
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SPC           71  400180      246                                       DATA  2098
SPC           71  410000      246                                       DATA  2099
SPC           71  410180      246                                       DATA  2100
SPC           71  420000      246                                       DATA  2101
SPC           71  420180      246                                       DATA  2102
SPC           71  430000      246                                       DATA  2103
SPC           71  430180      246                                       DATA  2104
SPC           71  440000      246                                       DATA  2105
SPC           71  440180      246                                       DATA  2106
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SPC           71  460180     246                                  DATA  2110
SPC           71  470000     246                                  DATA  2111
SPC           71  470180     246                                  DATA  2112
SPC           71  480000     246                                  DATA  2113
SPC           71  480180     246                                  DATA  2114
SPC           71  490000     246                                  DATA  2115
SPC           71  490180     246                                  DATA  2116
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SPC           71  500000     345                                  DATA  2118
SPC           71  500180     345                                  DATA  2119
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SPC           71  505180     345                                  DATA  2121
SPC           71  511000     345                                  DATA  2122
SPC           71  511180     345                                  DATA  2123
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SPC           71  521000     345                                  DATA  2126
SPC           71  521180     345                                  DATA  2127
SPC           71  526000     345                                  DATA  2128
SPC           71  526180     345                                  DATA  2129
SPC           71  532000     345                                  DATA  2130
SPC           71  532180     345                                  DATA  2131
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SPC           71  537180     345                                  DATA  2133
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SPC           71  542180     345                                  DATA  2135
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SPC           71  558180     345                                  DATA  2141
SPC           71  564000     345                                  DATA  2142
SPC           71  564180     345                                  DATA  2143
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SPC           71  569180     345                                  DATA  2145
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SPC           71  574180     345                                  DATA  2147
SPC           71  579000     345                                  DATA  2148
SPC           71  579180     345                                  DATA  2149
SPC           71  585000     345                                  DATA  2150
SPC           71  585180     345                                  DATA  2151
SPC           71  590000     345                                  DATA  2152
SPC           71  590180     345                                  DATA  2153
SPC      71     590500  345                                       DATA  2154
SPC           71  600000     246                                  DATA  2155
SPC           71  600180     246                                  DATA  2156
SPC           71  610000     246                                  DATA  2157
SPC           71  610180     246                                  DATA  2158
SPC           71  620000     246                                  DATA  2159
SPC           71  620180     246                                  DATA  2160
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SPC             71  630180      246                                              DATA  2162
SPC             71  640000      246                                              DATA  2163
SPC             71  640180      246                                              DATA  2164
SPC             71  650000      246                                              DATA  2165
SPC             71  650180      246                                              DATA  2166
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SPC             71  660180      246                                              DATA  2168
SPC             71  670000      246                                              DATA  2169
SPC             71  670180      246                                              DATA  2170
SPC             71  680000      246                                              DATA  2171
SPC             71  680180      246                                              DATA  2172
SPC             71  690000      246                                              DATA  2173
SPC             71  690180      246                                              DATA  2174
SPC             71  700000      246                                              DATA  2175
SPC             71  700180      246                                              DATA  2176
$                                                                                DATA  2177
$               (SID=72)  ANTI-SYM B.C. AT MIDPLANE CUTTING PIPE CIRCUM          DATA  2178
$                                                                                DATA  2179
SPC     72        200500  126                                                    DATA  2180
SPC             72  400000      135                                              DATA  2181
SPC             72  400180      135                                              DATA  2182
SPC             72  410000      135                                              DATA  2183
SPC             72  410180      135                                              DATA  2184
SPC             72  420000      135                                              DATA  2185
SPC             72  420180      135                                              DATA  2186
SPC             72  430000      135                                              DATA  2187
SPC             72  430180      135                                              DATA  2188
SPC             72  440000      135                                              DATA  2189
SPC             72  440180      135                                              DATA  2190
SPC             72  450000      135                                              DATA  2191
SPC             72  450180      135                                              DATA  2192
SPC             72  460000      135                                              DATA  2193
SPC             72  460180      135                                              DATA  2194
SPC             72  470000      135                                              DATA  2195
SPC             72  470180      135                                              DATA  2196
SPC             72  480000      135                                              DATA  2197
SPC             72  480180      135                                              DATA  2198
SPC             72  490000      135                                              DATA  2199
SPC             72  490180      135                                              DATA  2200
SPC     72        500500  126                                                    DATA  2201
SPC             72  500000      126                                              DATA  2202
SPC             72  500180      126                                              DATA  2203
SPC             72  505000      126                                              DATA  2204
SPC             72  505180      126                                              DATA  2205
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SPC             72  511180      126                                              DATA  2207
SPC             72  516000      126                                              DATA  2208
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SPC             72  526180      126                                              DATA  2213
SPC             72  532000      126                                              DATA  2214
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SPC           72  542180      126                                          DATA  2219
SPC           72  548000      126                                          DATA  2220
SPC           72  548180      126                                          DATA  2221
SPC           72  553000      126                                          DATA  2222
SPC           72  553180      126                                          DATA  2223
SPC           72  558000      126                                          DATA  2224
SPC           72  558180      126                                          DATA  2225
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SPC           72  564180      126                                          DATA  2227
SPC           72  569000      126                                          DATA  2228
SPC           72  569180      126                                          DATA  2229
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SPC           72  579180      126                                          DATA  2233
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SPC           72  585180      126                                          DATA  2235
SPC           72  590000      126                                          DATA  2236
SPC           72  590180      126                                          DATA  2237
SPC     72       590500  126                                               DATA  2238
SPC           72  600000      135                                          DATA  2239
SPC           72  600180      135                                          DATA  2240
SPC           72  610000      135                                          DATA  2241
SPC           72  610180      135                                          DATA  2242
SPC           72  620000      135                                          DATA  2243
SPC           72  620180      135                                          DATA  2244
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SPC           72  650180      135                                          DATA  2250
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SPC           72  660180      135                                          DATA  2252
SPC           72  670000      135                                          DATA  2253
SPC           72  670180      135                                          DATA  2254
SPC           72  680000      135                                          DATA  2255
SPC           72  680180      135                                          DATA  2256
SPC           72  690000      135                                          DATA  2257
SPC           72  690180      135                                          DATA  2258
SPC           72  700000      135                                          DATA  2259
SPC           72  700180      135                                          DATA  2260
$                                                                          DATA  2261
$       ELIMINATION OF ZERO STIFFNESS DOF                                  DATA  2262
$                                                                          DATA  2263
SPC           80  400000        4                                          DATA  2264
SPC           80  400180        4                                          DATA  2265
SPC           80  410000        4                                          DATA  2266
SPC           80  410180        4                                          DATA  2267
SPC           80  420000        4                                          DATA  2268
```

```
SPC           80  420180       4                                        DATA  2269
SPC           80  430000       4                                        DATA  2270
SPC           80  430180       4                                        DATA  2271
SPC           80  440000       4                                        DATA  2272
SPC           80  440180       4                                        DATA  2273
SPC           80  450000       4                                        DATA  2274
SPC           80  450180       4                                        DATA  2275
SPC           80  460000       4                                        DATA  2276
SPC           80  460180       4                                        DATA  2277
SPC           80  470000       4                                        DATA  2278
SPC           80  470180       4                                        DATA  2279
SPC           80  480000       4                                        DATA  2280
SPC           80  480180       4                                        DATA  2281
SPC           80  490000       4                                        DATA  2282
SPC           80  490180       4                                        DATA  2283
SPC           80  600000       4                                        DATA  2284
SPC           80  600180       4                                        DATA  2285
SPC           80  610000       4                                        DATA  2286
SPC           80  610180       4                                        DATA  2287
SPC           80  620000       4                                        DATA  2288
SPC           80  620180       4                                        DATA  2289
SPC           80  630000       4                                        DATA  2290
SPC           80  630180       4                                        DATA  2291
SPC           80  640000       4                                        DATA  2292
SPC           80  640180       4                                        DATA  2293
SPC           80  650000       4                                        DATA  2294
SPC           80  650180       4                                        DATA  2295
SPC           80  660000       4                                        DATA  2296
SPC           80  660180       4                                        DATA  2297
SPC           80  670000       4                                        DATA  2298
SPC           80  670180       4                                        DATA  2299
SPC           80  680000       4                                        DATA  2300
SPC           80  680180       4                                        DATA  2301
SPC           80  690000       4                                        DATA  2302
SPC           80  690180       4                                        DATA  2303
SPC           80  700000       4                                        DATA  2304
SPC           80  700180       4                                        DATA  2305
$                                                                       DATA  2306
$       CONSTRAIN FIXED END                                             DATA  2307
$                                                                       DATA  2308
SPC           85  700000  123456                                        DATA  2309
SPC           85  700015  123456                                        DATA  2310
SPC           85  700030  123456                                        DATA  2311
SPC           85  700045  123456                                        DATA  2312
SPC           85  700060  123456                                        DATA  2313
SPC           85  700075  123456                                        DATA  2314
SPC           85  700090  123456                                        DATA  2315
SPC           85  700105  123456                                        DATA  2316
SPC           85  700120  123456                                        DATA  2317
SPC           85  700135  123456                                        DATA  2318
SPC           85  700150  123456                                        DATA  2319
SPC           85  700165  123456                                        DATA  2320
SPC           85  700180  123456                                        DATA  2321
$                                                                       DATA  2322
```

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SPCADD  91      71      80      85                                              DATA  2323
SPCADD  92      72      80      85                                              DATA  2324
ENDDATA                                                                         DATA  2325
```

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